04.2021

NATIONAL GEOGRAPHIC

THE FIGHT FOR CLEAN AIR

Air pollution causes 7 million premature deaths a year.
But we can fix it.

PAID CONTENT FOR PFIZER

From Outbreak To Immunity

An English country doctor's bold use of one contagion to fight another in 1796 ushered in the modern era of immunology. By then, though, the idea that something virulent could be made beneficial was not new. The painful, deadly variola virus had killed hundreds of millions, but it also revealed a fundamental insight: Pus from smallpox patients' sores could protect the uninfected.

This early version of inoculation against smallpox, known as variolation, was practiced around the world for centuries. Our experience with the novel coronavirus is far shorter, and the lessons it has for us have not yet concluded. But more than 220 years of vaccine development have led humans to the current moment. We are witnessing another historic breakthrough, this time with an entirely new method of fighting disease.

Pfizer

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The Cowpox Connection

The smallpox vaccine was a departure from variolation because it employed a similar but less dangerous virus: cowpox. The country doctor, Edward Jenner, theorized that dairy workers in Gloucestershire routinely contracted the latter, but they seemed to escape the dreaded smallpox. He verified the effect by inoculating an eight-year-old boy with fluid from a woman's cowpox lesions.

After the inoculation, young James Phipps did not develop smallpox, despite deliberate exposure. Jenner detailed the findings from this and other experiments shortly afterward, deriving the word vaccine from the Latin word for cow, *vacca*.

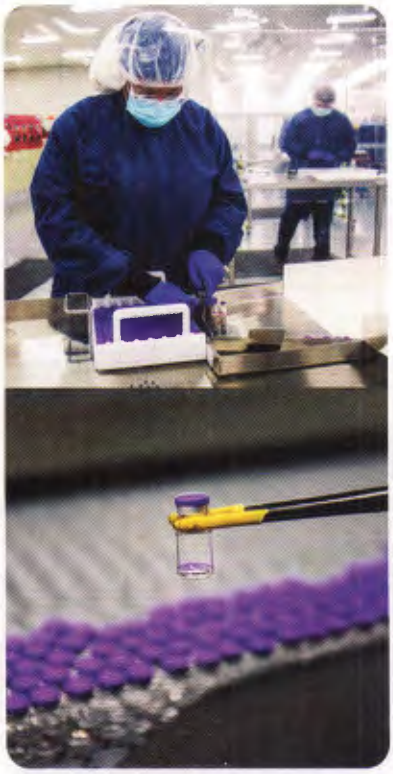
The U.S. established a national vaccine agency in 1813 to encourage smallpox immunizations, and the 20th century saw a succession of landmark vaccines for polio, mumps, measles, and other devastating illnesses.

"There are so many lessons that this pandemic taught us, and they touch the spectrum of human activities..."

Scientists have developed a variety of ways to jump start the body's immune system by exposing it to a pathogen. Some use a dead or weakened form of the germ; others use only specific parts of the virus or bacteria to produce an immune response. No matter the type, an ideal vaccine will spark an immune response, stimulating the body's white blood cells to fight off the real thing if exposure occurs.

Cutting-Edge Science

The latest generation of vaccine development uses new and different ways to further refine the body's response to infectious disease. In mRNA vaccines, messenger RNA—essentially a set of genetic instructions—tells the body to produce a benign protein unique to the virus, training it to fend off an attack.



Two of the COVID-19 vaccines that have been developed are based on mRNA technology—one from Pfizer, developed with BioNTech using its proprietary mRNA technology, and a second from Moderna. Each capitalizes on the fact that in early January 2020, Chinese researchers released the genetic sequence for the virus, which is related to the one that caused the outbreak of Severe Acute Respiratory Syndrome (SARS) in 2003.

From the outset of Pfizer's vaccine development process, CEO Albert Bourla said the company would move "at the speed of science" while ensuring patient safety remained a priority. With several other companies reaching the final stages of testing their own vaccines within a year of the initial outbreak, the speed of science has been astonishingly swift. Before this one, the fastest vaccine ever developed was for the mumps—that took four years.

If smallpox taught the world how to make vaccines, coronavirus may teach us how to make them faster than ever. And while the virus still poses many unanswered questions, it also illustrates how a crisis can spark global innovation.

"There are so many lessons that this pandemic taught us, and they touch the spectrum of human activities," Bourla said. "[But] something that really stands out, I think, is the lesson of the power of science."

The Pfizer-BioNTech COVID-19 vaccine has not been approved or licensed by the U.S. Food and Drug Administration (FDA), but has been authorized for emergency use by the FDA under an Emergency Use Authorization (EUA) to prevent Coronavirus Disease 2019 (COVID-19) for use in individuals 16 years of age and older. The emergency use of this product is only authorized for the duration of the declaration that circumstances exist justifying the authorization of emergency use of the medical product under Section 564(b)(1) of the FD&C Act unless the declaration is terminated or authorization revoked sooner. Please see EUA Fact Sheet at www.cvdvaccine.com.

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AIR POLLUTION

An Environmental Problem We Can Fix

BY **SUSAN GOLDBERG** PHOTOGRAPH BY **MATTHIEU PALEY**

IT'S HARD TO IMAGINE places more different from one another than Delhi, India; Mexico City, Mexico; and Gary, Indiana. Yet years after I visited those cities, they're indelibly linked in my memory for one reason: the foul, polluted air smothering their landscapes. The pollution was so heavy you could see it wafting through the interiors of modern buildings (Delhi, 2016), feel it stinging your eyes (Mexico City, 1972), and smell it through closed car windows (Gary, the 1960s).

Despite its ubiquity, or perhaps because of it, air pollution has rarely gotten the sustained attention it deserves. That's an outrage, given that air pollution is a global killer, causing an astonishing seven million premature deaths every year. But it's also an opportunity, because this is an environmental problem that we actually can fix.

There's no better example of that than the experience of the United States, which last year celebrated the 50th anniversary of the Clean Air Act. Signed by President Richard Nixon on December 31, 1970, this single statute resulted in a 77 percent decrease in the nation's air pollution. It lengthened millions of American lives, saved trillions of dollars, and according to the American Lung Association's Paul Billings, became "the most powerful public health law enacted in the 20th century."

Those of us of a certain age can vividly recall its impact. Think of Los Angeles 50 years ago, or Pittsburgh, or so many other locales where the horizon was a haze and grime settled on your car overnight. The Clean Air Act has been "the difference maker," in Billings's words—leaving many U.S. communities' air quality "so much better than it was, and so much better than it is in other parts of the world."

People play on the ice of the Tuul River south of Ulaanbaatar, Mongolia, with the city's foul air in the background. Coal burned in homes and power plants makes Ulaanbaatar one of the most polluted capitals on Earth. Writer Beth Gardiner and photographer Matthieu Paley visited the city while reporting this issue's cover story.

Still, the problem is far from solved, as pollution expert Beth Gardiner and photographer Matthieu Paley found in reporting this month's cover story. Air pollution disproportionately harms the poor and people of color who live where it's worst. And after four years of a U.S. administration that gutted regulations, the Clean Air Act "has survived, but it has been damaged," says environmentalist Mustafa Santiago Ali.

Though there will be challenges, Ali is convinced that the time is right to build on the act's achievements. "You have a new generation that understands how important it is to have clean air," he says. "I hope we'll come to a point in our history, sometime soon, where not only do we understand the value of [the act], but we're willing to do the hard work of enhancing it."

Thank you for reading *National Geographic*. ◻

Introducing ATEM Mini

The compact television studio that lets you create presentation videos and live streams!

Blackmagic Design is a leader in video for the television industry, and now you can create your own streaming videos with ATEM Mini. Simply connect HDMI cameras, computers or even microphones. Then push the buttons on the panel to switch video sources just like a professional broadcaster! You can even add titles, picture in picture overlays and mix audio! Then live stream to Zoom, Skype or YouTube!

Create Training and Educational Videos

ATEM Mini's includes everything you need. All the buttons are positioned on the front panel so it's very easy to learn. There are 4 HDMI video inputs for connecting cameras and computers, plus a USB output that looks like a webcam so you can connect to Zoom or Skype. ATEM Software Control for Mac and PC is also included, which allows access to more advanced "broadcast" features!

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ATEM Mini is really a professional broadcast switcher used by television stations. This means it has professional effects such as a DVE for picture in picture effects commonly used for commentating over a computer slide show. There are titles for presenter names, wipe effects for transitioning between sources and a green screen keyer for replacing backgrounds with graphics.

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The ATEM Mini Pro model has a built in hardware streaming engine for live streaming via its ethernet connection. This means you can live stream to YouTube, Facebook and Teams in much better quality and with perfectly smooth motion. You can even connect a hard disk or flash storage to the USB connection and record your stream for upload later!

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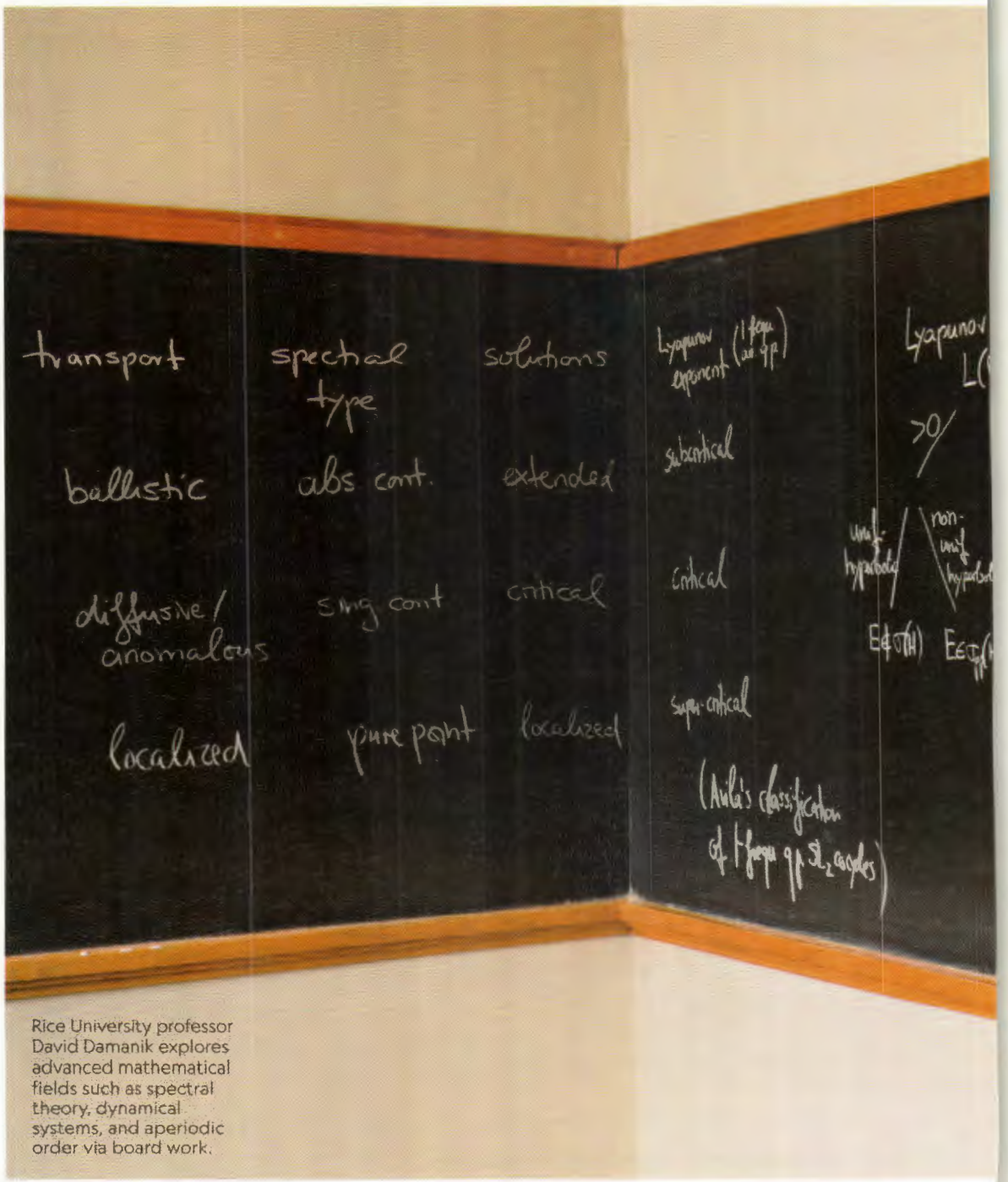
PHOTOGRAPHS BY **JESSICA WYNNE**

LOOKING AT THE EARTH FROM EVERY POSSIBLE ANGL



Rice University professor David Damanik explores advanced mathematical fields such as spectral theory, dynamical systems, and aperiodic order via board work.

THE FINE ART OF BOARD WORK

With chalkboard as canvas, mathematicians create new forms of language and art.

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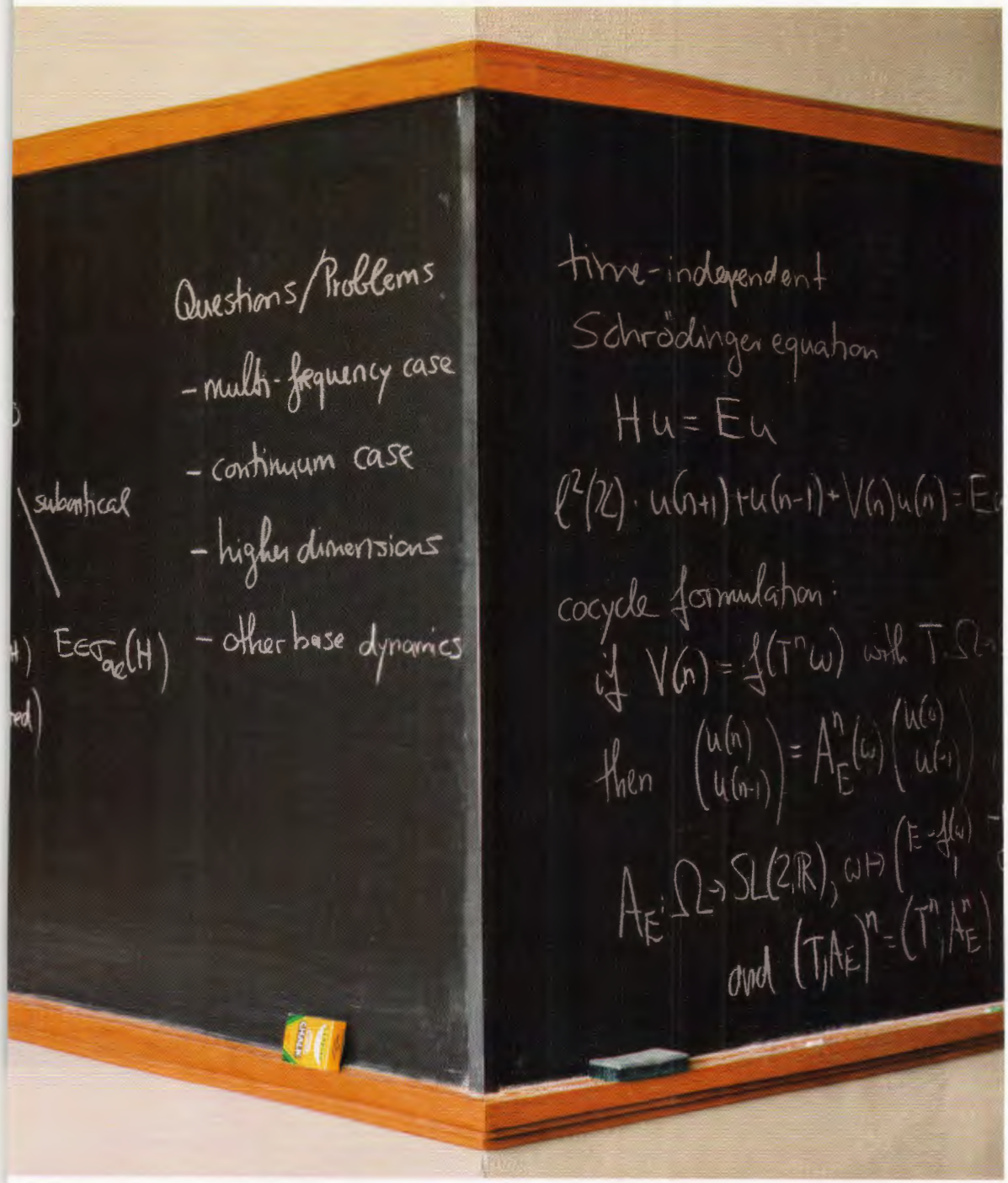
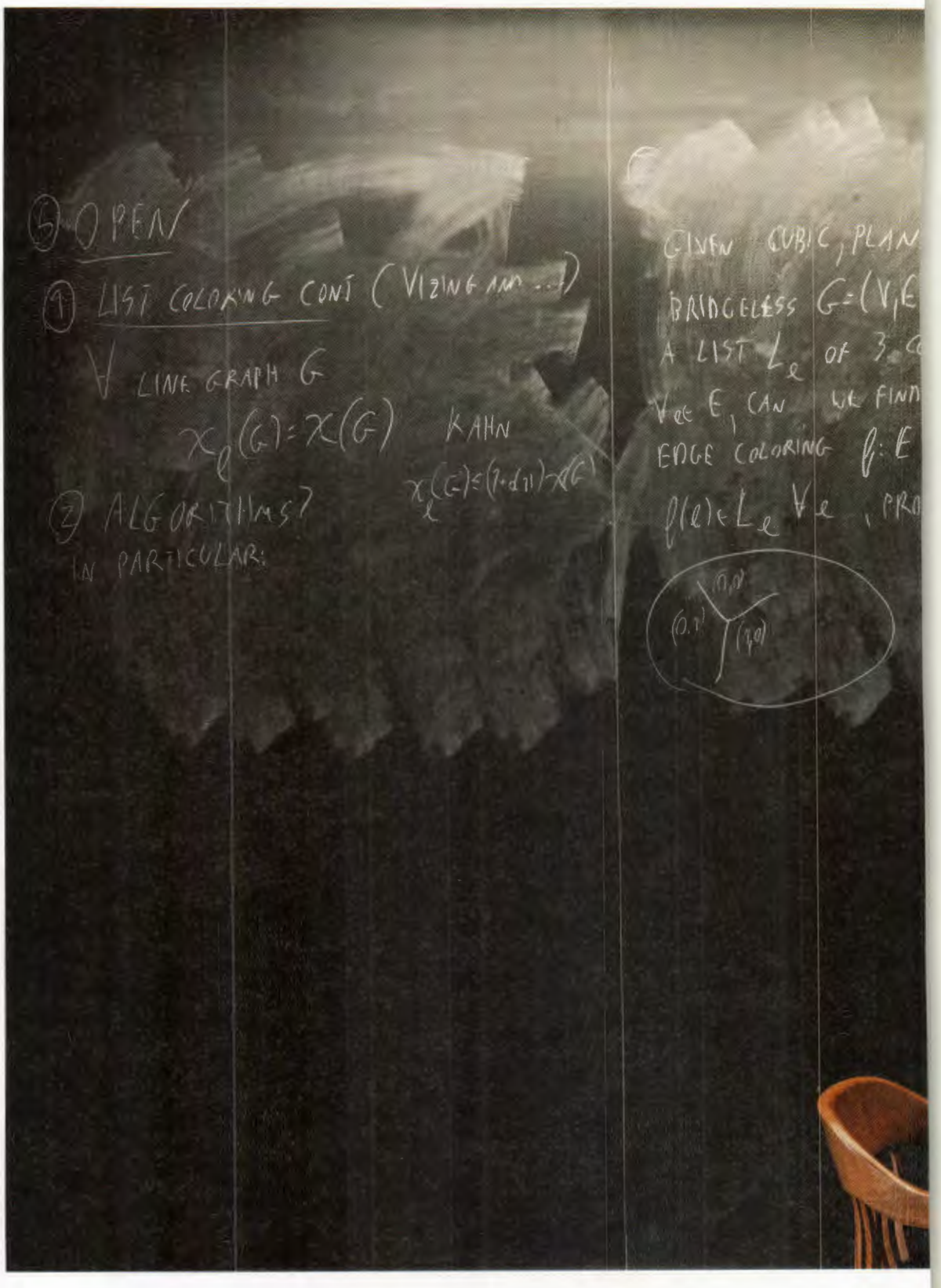
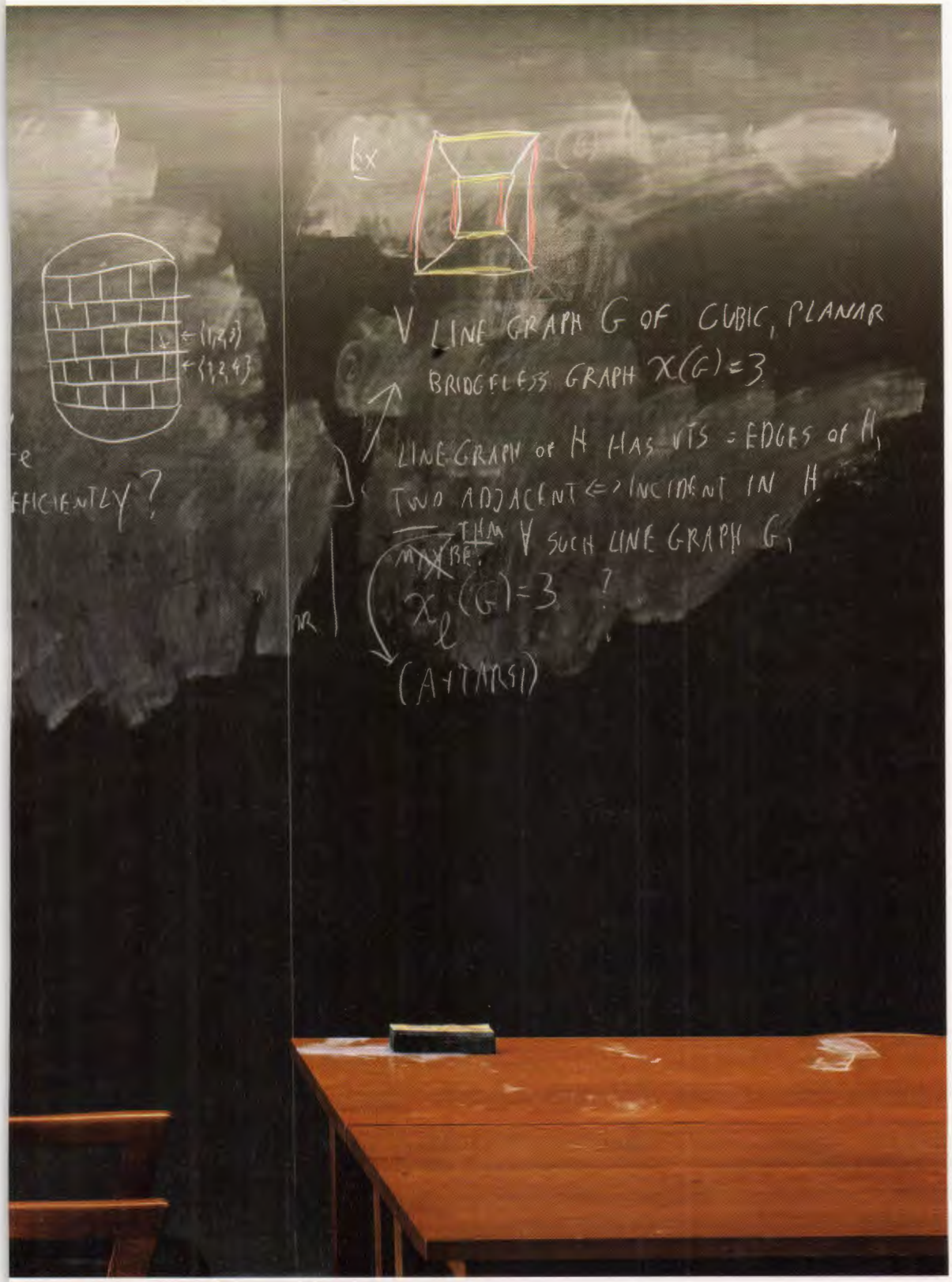




Ideas explored on chalkboards—and erased and explored again and again—can lead to breakthroughs across disciplines, particularly in mathematics. At Princeton University, professor Noga Alon uses his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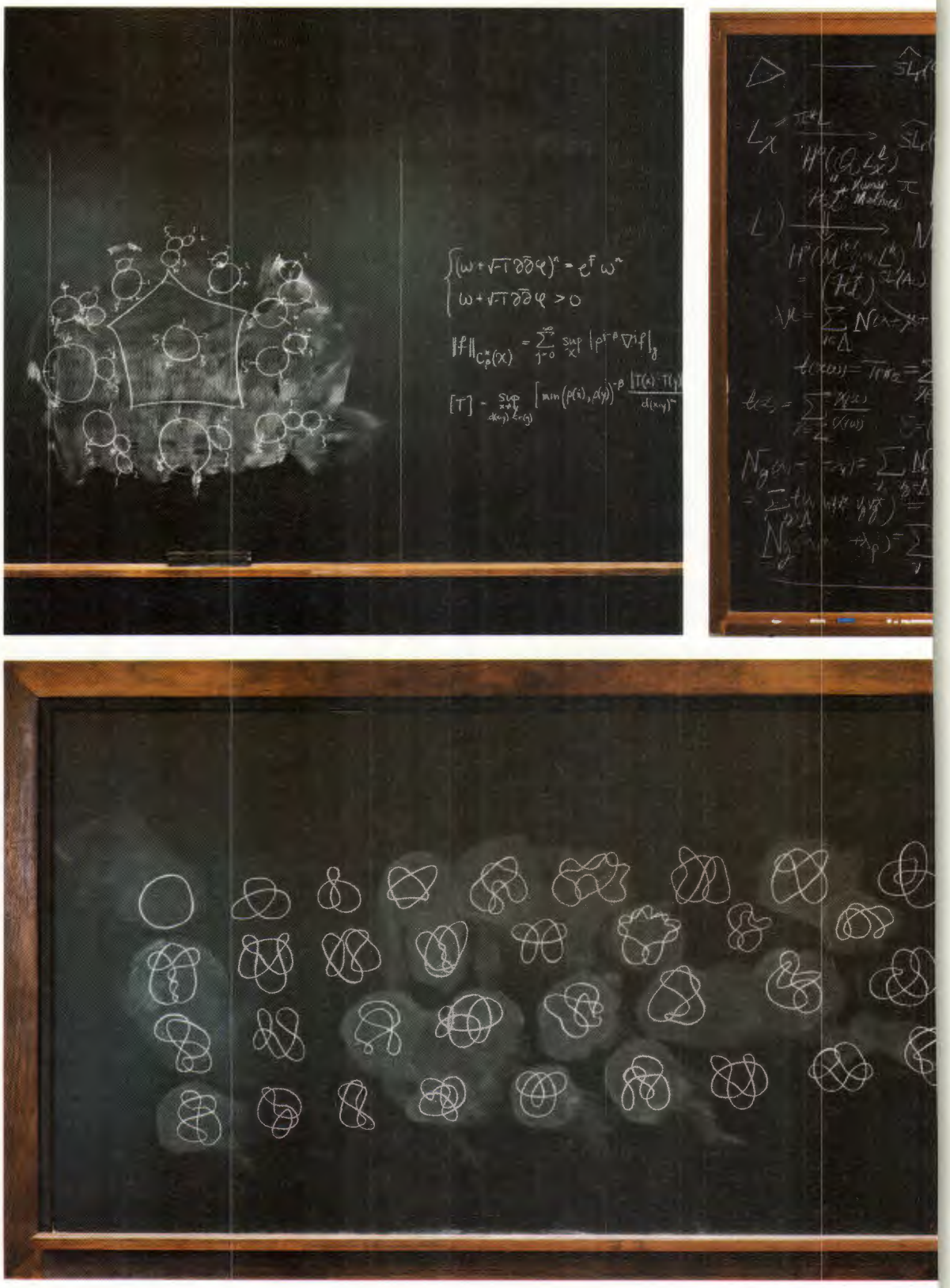
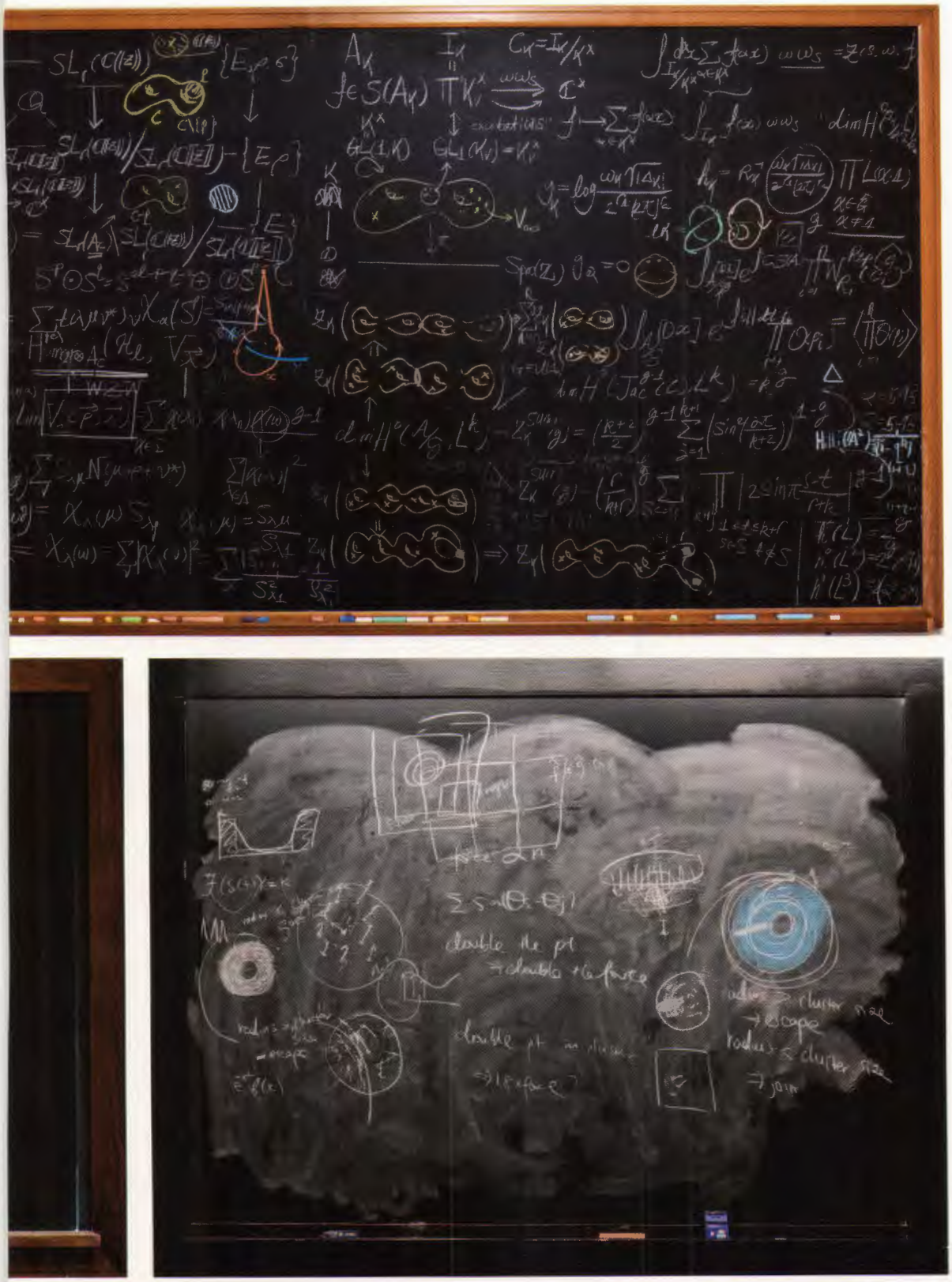
board to study how graph theory can be applied to computer science, a relationship that has enabled modern advances in digital technology.



Chalkboard calculations and ruminations can appear bafflingly complex. Clockwise from top left, these boards show the work of graduate student Zhongyi Zhang at Columbia University in New York City,



graduate student Shuai Wang at Columbia University, graduate student Boya Song at MIT in Cambridge, Massachusetts, and graduate student Sahar Khan at Columbia University.

THE BACKSTORY

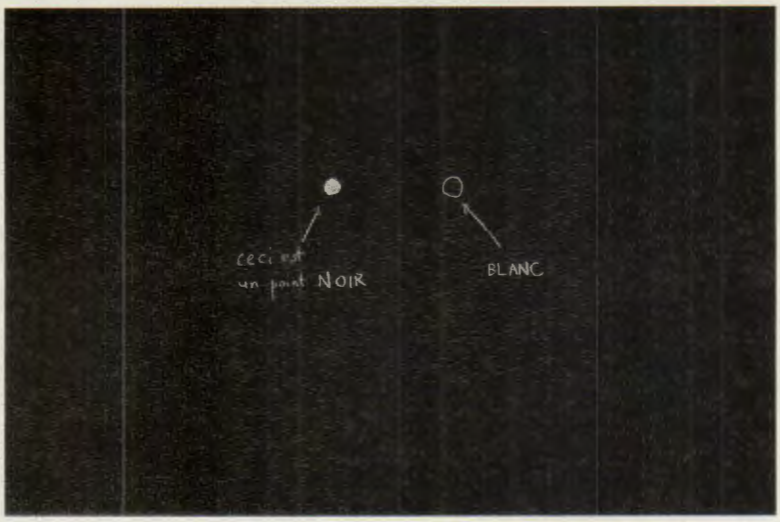
OBSOLETE? HARDLY. CHALKBOARDS REMAIN A TIMELESS TOOL FOR WORKING OUT THE MOST COMPLEX PROBLEMS.

DETRACTORS MAY deride mathematics as difficult, abstract, rigid, boring. But to admirers, mathematics is fascinating, creative, even an art form—and its canvases are chalkboards covered with scribbles, an odd mix of therapy and ingenuity known as board work.

Photographer Jessica Wynne learned about the beauty of mathematics from her summer neighbors on Cape Cod, Massachusetts. Both of them are theoretical mathematicians, and when their friends—also theoretical mathematicians—came over, Wynne noticed that chalkboard ponderings were how they communicated complex ideas and worked out knotty problems. They used chalkboards to collaborate and spar and, most of all, to explore the boundaries of known mathematics. Some described it as meditation.

In a world with plenty of paper, whiteboard, and digital screen space, why chalk? "That's like asking a painter why they paint with oils," says Wynne. But there are practical matters too, she says. Dry-erase markers stain clothes and hands. Then there's how chalk sounds and feels when in use: a soft knock and rhythm, almost like a metronome. One University of Chicago mathematician vowed that if the math department replaced chalkboards with whiteboards, the faculty would revolt.

The quandaries of theoretical math are far more difficult than solving for *x* or balancing the quadratic equation. Some mathematicians try to find new universal truths, as Archimedes discovered pi and Pythagoras defined a right triangle. Board work also may be an end in itself—a place to record one's thoughts, unrushed. Wynne photographed one heavily notated board, at Yale University, on which the professor had written in one corner: "Pls do not erase." It had remained untouched for five years. **–DANIEL STONE**



At Stanford University in California, mathematics professor Tadashi Tokieda does research in applied mathematics and macroscopic physics—though this day's board work also shows off his French.

IMAGES VIA EDWYNN HOUK GALLERY

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ARNOLD
ORGANIC
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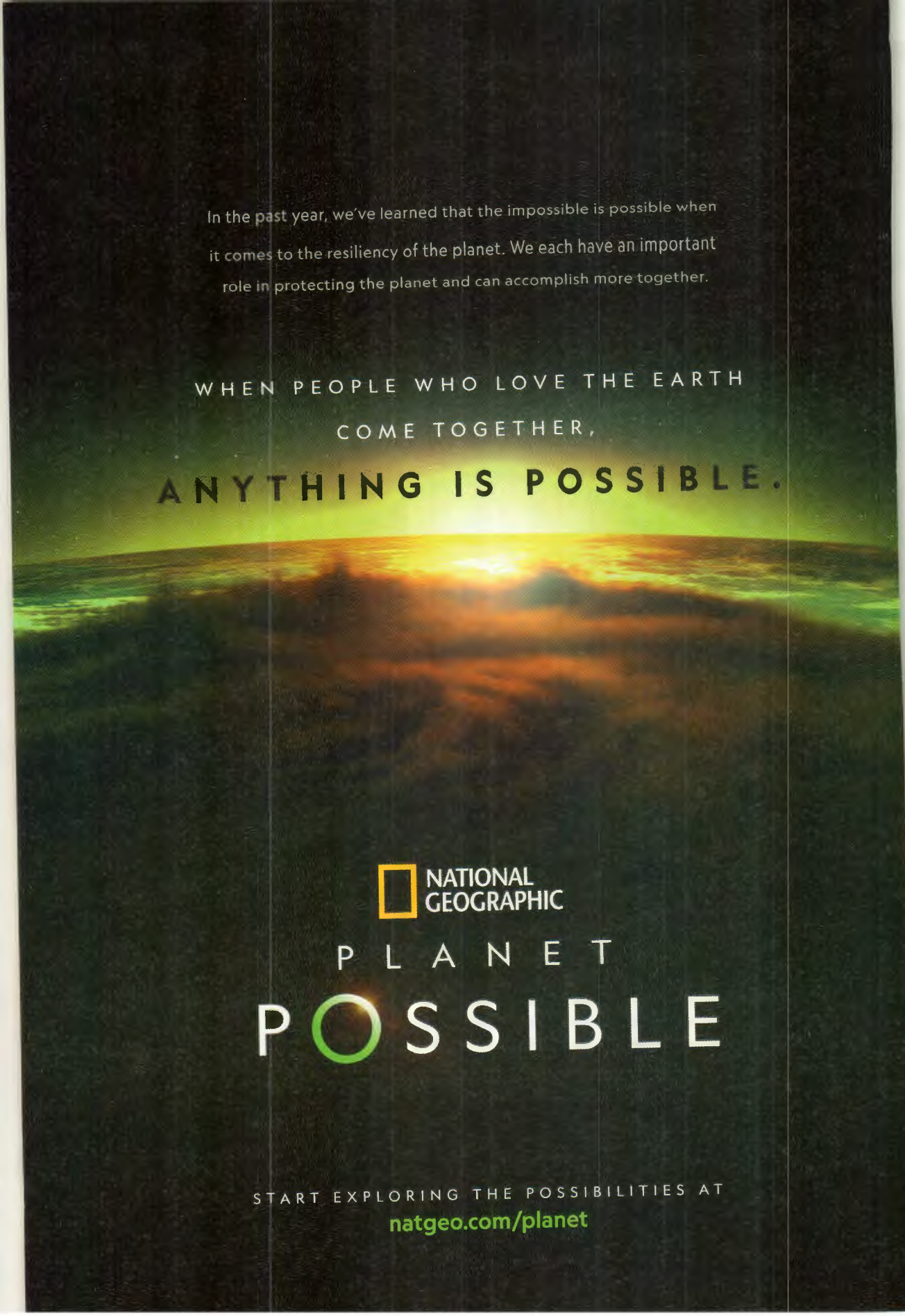
In the past year, we've learned that the impossible is possible when it comes to the resiliency of the planet. We each have an important role in protecting the planet and can accomplish more together.
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The Indelible Legacy of Land

TO BLACK AMERICAN FAMILIES LIKE MINE, SOIL HAS NEVER BEEN SIMPLE. IT REPRESENTS LOSS, DREAMS, INJUSTICE, AND SELF-RELIANCE.

BY **NATALIE BASZILE**

BEFORE MY HUSBAND AND I moved to San Francisco, we lived in Southern California, in a glistening beach town along the coast a few miles south of Los Angeles International Airport. The yard of our ranch-style house opened onto a half-acre-wide easement overgrown with fennel, sage scrub, and wild mustards. It was city-owned land, permanently set aside as open space, and soon after moving in, I "borrowed" some for a vegetable garden. I cleared the land by hand, ordered a truckload of topsoil, then built 14 10-by-12-foot raised beds in which I planted heirloom tomatoes, cucumbers, carrots, green beans, beets, and leafy greens. My parents lived three blocks away. In the evenings after work, and often on Saturday mornings, they came over to help me tend the garden.

In my family, dirt had never been simple. Like so many African-American families, we had a long and complicated relationship with land and soil. For us,

MY FATHER CAME OF AGE IN AN ERA WHEN BEING BLACK AND OWNING LAND SPARKED RESENTMENT, WHEN CLAIMING A PIECE OF GROUND AS YOUR OWN COULD GET YOU KILLED.

having the garden was never just about planting seeds and watching them grow. The garden served as a connection to a painful past, invited us to celebrate our progress, and gestured toward the future. Our garden honored our forefathers' triumphs and memorialized their struggles. It was about memory and legacy—our family's and this nation's. The garden told a story about what it meant to be Black in America.

By day, my dad was an entrepreneur and a business owner. But when he came over, he'd kick off his Johnston & Murphy wing tips, roll up his pant legs, and walk barefoot between the garden rows. He was born and raised in rural south Louisiana and declared that of all the things he loved in the world, he loved to feel his feet in the dirt most of all. He said the sensation of warm earth underfoot reminded him of his boyhood—an adolescence spent hunting and fishing, picking cotton and planting rice.

But my father's life in Louisiana hadn't been easy or romantic. He held no nostalgia for the South. As much as he loved the feeling of his feet in the dirt, he hated what southern soil represented. He grew up during Jim Crow segregation, under the constant threat of violence, intimidation, and terror at the hands of white supremacists determined to impede Black people's progress. He came of age during an era when being Black and owning land sparked resentment; when claiming a piece of ground as your own, to farm or set up a business, could get you killed.

In 1957 my dad left Louisiana for good, knowing that the brightest horizon of his future couldn't unfold on the land of his birth. He was swept up in one of the waves of the Great Migration, the period from about 1916 to 1970 when six million African Americans left the rural South for better opportunities in the industrial Northeast, Midwest, and West. He moved to California, trading Louisiana's rice fields and twisting bayous for Los Angeles's sandy beaches and sprawling coastline. He worked as a probation officer, then found his way into sales. Eventually, he opened his own business—something that would never have happened back home. His business created the path to upward mobility for his family. For my dad, staying close to the land meant foreclosing opportunities. The only way to succeed was to uproot himself and abandon his native soil.

He never lived in Louisiana again, but my dad always said that Louisiana dirt shaped him profoundly; that no matter what he achieved, he defined himself—emotionally, spiritually, intellectually, and

The deceit of '40 Acres and a Mule'

On January 12, 1865, in Savannah, Georgia, Union secretary of war Edwin Stanton and Maj. Gen. William T. Sherman met with 20 Black ministers speaking for four million newly emancipated Black people. What will your people do to sustain themselves? the warriors asked the pastors.

Baptist minister Garrison Frazier answered. "The best way we can take care of ourselves is to have land," he said. "We want to be placed on land until we are able to buy it and make it our own."

Four days later, Sherman obliged. With Special Field Order 15, he directed that more than 400,000 acres of confiscated Confederate land be distributed to formerly enslaved people. Under the mandate, eventually named "40 Acres and a Mule," nearly 40,000 Black Americans were settled within six months.

The land grant was short-lived. After President Abraham Lincoln was assassinated, his successor, Andrew Johnson, moved to pacify white Confederate planters—by repealing Order 15 and returning their land. And yet, in the face of America's broken promise, for decades after Emancipation, and despite the failure of Reconstruction and the rise of Jim Crow segregation, Black people have toiled and sacrificed to realize their dream of owning land. —NB

Library of Congress Collection photographs from 1936 to 1941 depict Black Americans on the land (clockwise from top left): driving a horse team in New York, tending a cotton field in Georgia, hoeing in a field in Alabama, and tenant farming in Georgia.

culturally—by the land from which he'd come. For better and for worse, Louisiana soil was in his blood.

My mother had a different relationship to dirt. She came from a long line of people who saw dirt as an opportunity. Born in Detroit, Michigan, she was raised understanding that landownership was the path to self-reliance and financial independence. Even in the South, unlike my father's family, her people owned and worked the land. Her great-grandfather, Mac Hall, was born in 1845. After Emancipation, he left the plantation to settle in nearby Georgiana, Alabama. He became a merchant, beekeeper, and farmer, eventually acquiring more than 600 acres.

For Mac Hall and four million other newly emancipated Black people, landownership held the promise of self-determination. Being a male landowner meant having status in the community, paying taxes, and exercising the right to vote. Owning land promised the opportunity to build and accrue wealth that could be passed down through generations. In other words, owning dirt meant asserting one's identity as an American citizen and exercising control over one's fate.

My mother's parents, Mamon and Willa, immigrated to Detroit in the early years of the Great Migration, expecting to own land again. By the mid-1930s they had purchased 11 vacant lots in Royal Oak Township, a majority-Black neighborhood outside of Detroit. Those lots were, in their own way, Mamon and Willa's version of a family farm. On one lot they built two houses: one for themselves and their children, and one for their parents. After Mamon was killed by a drunk driver, Willa converted the garage into two apartments that she rented to newly arrived Black migrants from "down South." She was not just a landowner but a landlord, providing shelter to other Black people looking to improve their lives.

Over the years, Willa sold a vacant lot whenever she needed money but always kept one for her vegetable garden. She fed herself and her five daughters, at least partially, from the cabbage, string beans, and collards she grew. Being able to provide food and shelter for her family from the dirt she owned meant that she never had to rely on anyone for her livelihood. Whether she planted petunias or grew food, her small garden plot was subversive. To Willa, dirt meant sovereignty, freedom, and independence.

Willa passed her belief in landownership down to my mother, who used some of her modest teacher's salary to buy property around Los Angeles. Now, on balmy evenings and bright Saturday mornings, my mom and I gardened side by side. Dressed in her gardening gloves and brimmed hat, she reminded me that landownership was in my family's DNA.

WHETHER MY GRANDMOTHER PLANTED PETUNIAS OR GREW FOOD, HER SMALL GARDEN PLOT WAS SUBVERSIVE. DIRT MEANT SOVEREIGNTY, FREEDOM, INDEPENDENCE.

I was grateful for my parents' stories and their southern roots. Working in the garden with them gave me a new perspective on their lives. They were people who understood that they couldn't sustain themselves and move ahead while maintaining a traditional relationship with the land. They'd had to make different choices. And yet they were keenly aware of how their drive and determination were born of the soil.

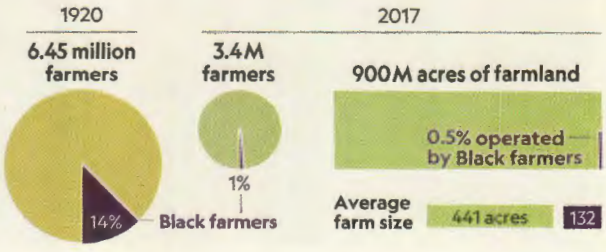
Now it was my turn to grapple with the past and ask a new, equally complex set of questions. I was native Californian, born and raised in the suburbs surrounded by manicured lawns and concrete. I had to forge my own relationship with the soil and pass that on to my children. I came to see the garden as a chance for my girls to bond with their grandparents and commune with their ancestors. I understood that I was the first in my family for whom gardening played a totally different role. For me, digging in the dirt was a hobby, an indulgence. The garden was a place of leisure and pleasure, a source of powerful memory and recollection.

For Black people, dirt will never be just one thing. There will always be a tension between soil and tradition, soil and progress, soil and freedom. We garden to reconcile that tension. To make a statement of how far we've come and where we're going. Gardening is our attempt to remember and forget, look ahead and reach back, hold tight and push forward. □

Natalie Baszile drew this essay from her new book, *We Are Each Other's Harvest*. She's also author of the novel *Queen Sugar*, adapted for television by Ava DuVernay and Oprah Winfrey.

FARMING INEQUALITY

Black farmers,* who make up just one percent of all farmers in the United States, have been disproportionately affected over the past century as the amount of farmland in the country, and the number of people farming it, have declined. Access to capital is a significant barrier.



*FARMERS WHO IDENTIFIED AS BLACK OR AFRICAN-AMERICAN, EITHER ALONE OR IN COMBINATION WITH ANOTHER RACE. THERE ARE DIFFERENCES IN METHODOLOGY BETWEEN 1920 AND 2017. LATEST AVAILABLE DATA.

DIANA MARQUES AND IRENE BERMAN-VAPORIS, NGM STAFF. SOURCE: USDA

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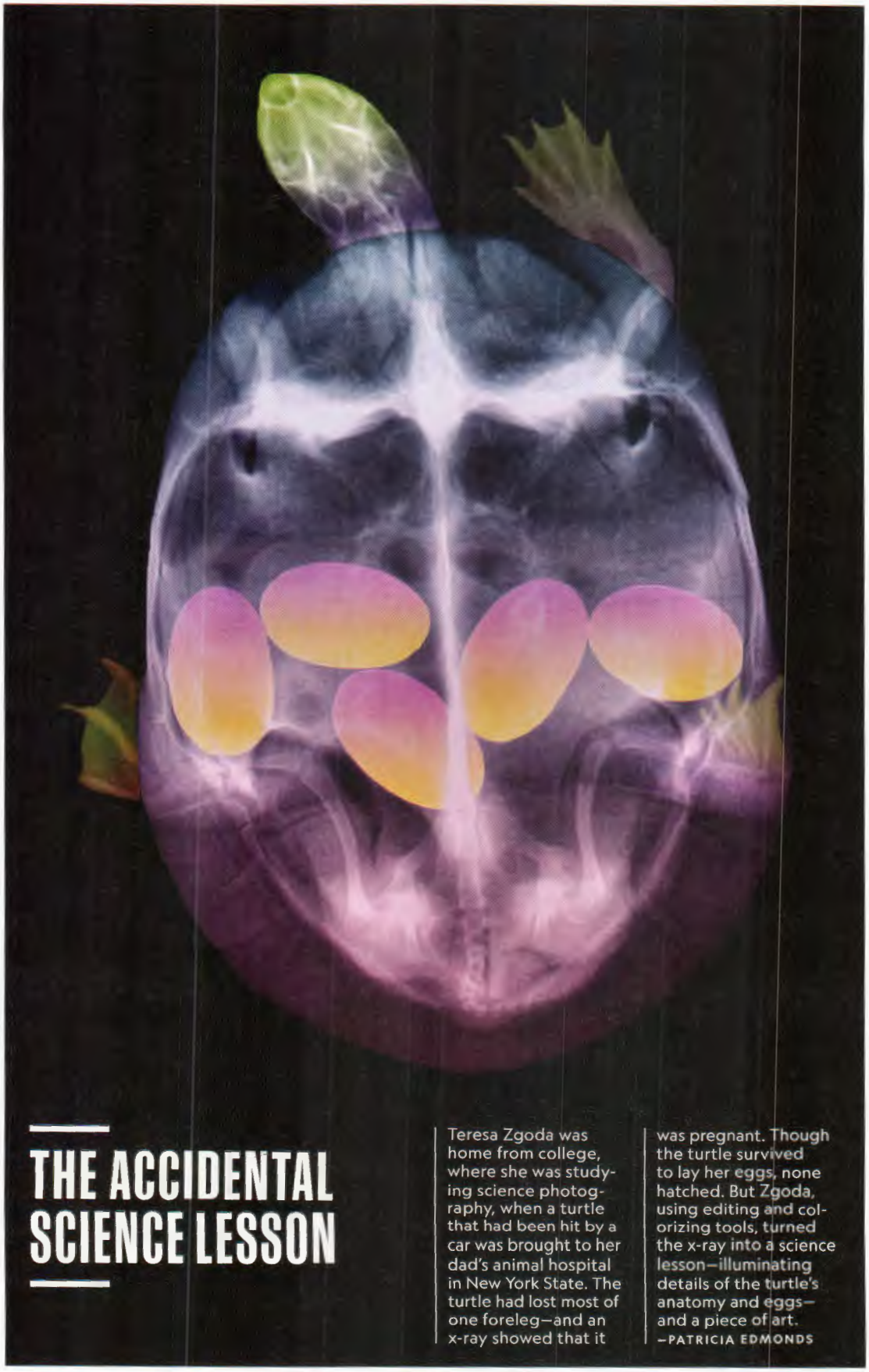

THE ACCIDENTAL SCIENCE LESSON

Teresa Zgoda was home from college, where she was studying science photography, when a turtle that had been hit by a car was brought to her dad's animal hospital in New York State. The turtle had lost most of one foreleg—and an x-ray showed that it was pregnant. Though the turtle survived to lay her eggs, none hatched. But Zgoda, using editing and colorizing tools, turned the x-ray into a science lesson—illuminating details of the turtle's anatomy and eggs—and a piece of art.
—PATRICIA EDMONDS

X-RAY IMAGE: OTTERKILL ANIMAL HOSPITAL, CAMPBELL HALL, NEW YORK

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DISPATCHES FROM THE FRONT LINES OF SCIENCE AND INNOVATION

Light-as-air solar collectors

In solar cell technology, what does ultralightweight mean? Thin and flexible enough to rest on a soap bubble. The cells can capture energy from indoor or outdoor light, their makers say, and could help power medical skin patches, sensors for drones, and other devices too slight for heavy batteries. –JS

CONSERVATION

THE PARAKEET PROBLEM

THEY MAY BE PRETTY, BUT THESE PARROTS ARE INVASIVE PESTS THAT THREATEN BIODIVERSITY.

IT SEEMS INCONGRUOUS: fluorescent-green tropical birds totally at home in a park in Hesse, Germany (above). Are they fugitives from a tearoom or a pirate ship? No—just opportunistic avians that escaped or were released into the wild and quickly multiplied.

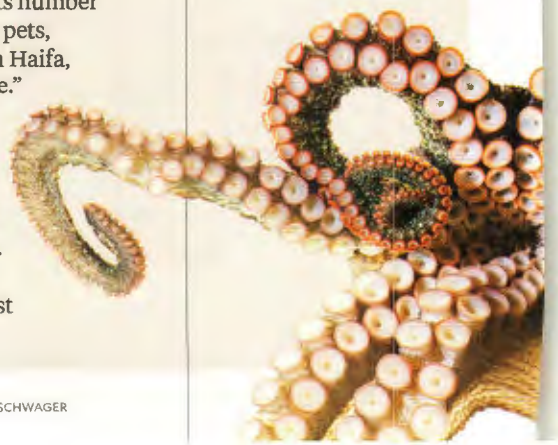
Rose-ringed parakeets, native to South Asia, were sold as pets until trade in wild birds was banned in the U.S. and Europe. Now they and monk parakeets have gone from pet to pest in Hawaii, California, and Florida, as well as in Europe (where rose-ringed parakeets number more than 85,000) and the Middle East. "They are very lousy pets, to be honest," says Assaf Shwartz, a conservation biologist in Haifa, Israel. "They're noisy; they bite. Owners get tired after a while." They destroy crops, menace native birds, and are displacing a threatened bat species in Spain. Monk parakeets' bulky nests on utility lines have caused power outages.

Eradication campaigns in the Canary Islands and the Seychelles have paired the trapping and shooting of invasives with advocacy in communities to promote native bird species. Still, any effort to thin the parakeet population can be controversial. After all, says British biodiversity conservationist Jim Groombridge, "people love parrots." –AMY ALIPIO

BIOENGINEERING

Scientists learn from octopus arm movements

It's one thing to marvel at an octopus's flexibility, and another to quantify it. Marine Biological Lab researchers watched 10 wild-caught octopuses attempt various tasks for two hours—and counted a total of 16,563 arm movements. Studying the mollusks' moves could help engineers design versatile, strong "soft robotic" arms for use in dangerous rubble inspections or delicate surgical procedures.
–JORDAN SALAMA



PHOTOS (FROM TOP): ANASTASIA SERIN, KAUST; BLICKWINKEL/ALAMY STOCK PHOTO; DAVID LIITTSCHWAGER

Tears From a Volcano

Uniquely American stone ignites romance

On May 18, 1980, the once-slumbering Mount St. Helens erupted in the Pacific Northwest. It was the most impressive display of nature's power in North America's recorded history. But even more impressive is what emerged from the chaos... a spectacular new creation born of ancient minerals named Helenite. Its lush, vivid color and amazing story instantly captured the attention of jewelry connoisseurs worldwide. You can now have four carats of the world's newest stone for an absolutely unbelievable price.

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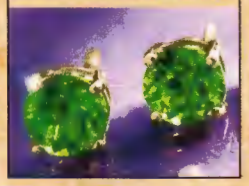

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INNOVATOR

JEREMY BAILENSON

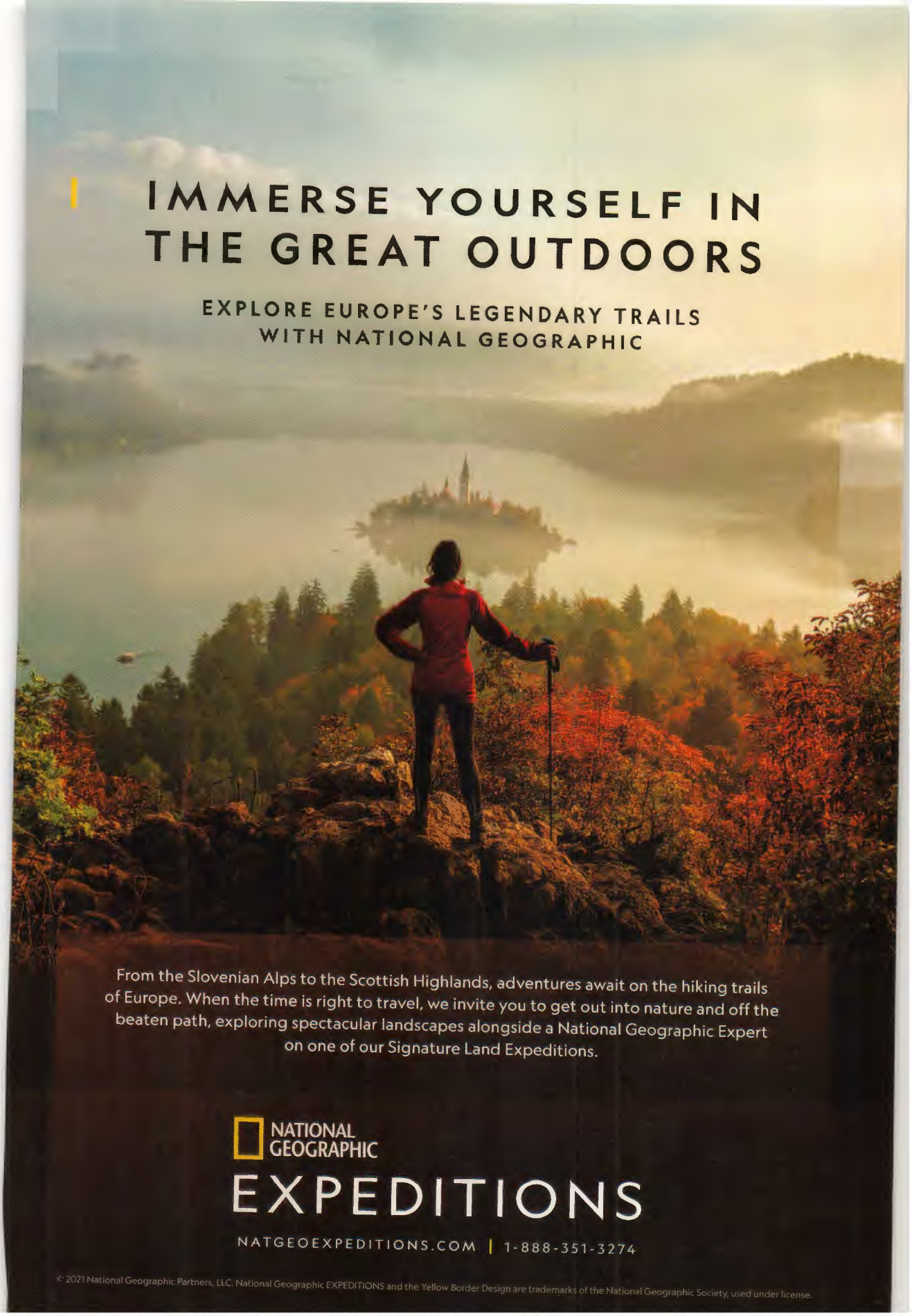
BY **THERESA MACHEMER** PHOTOGRAPH BY **BENEDICT EVANS**

He studies how recent work-at-home practices affect well-being.

Though many of us dread public speaking, the proliferation of video calls during the pandemic has "made listeners become speakers," says Jeremy Bailenson, founding director of the Virtual Human Interaction Lab at Stanford University. Before COVID-19, there had been very few studies of how hours of video calls might affect mental health, Bailenson says. Now that his lab has surveyed thousands of remote workers, he can list aspects of video calls that make people anxious—and recommend ways to mitigate them.

One source of anxiety for users is seeing their reflection in real time; that video feed should be hidden by default, Bailenson says. Another stressor: the size at which others appear on your screen. Bailenson says that in a typical one-on-one video call, your counterpart seems to be less than two feet away—and that's an uncomfortably intimate distance. He suggests setting a default maximum head size to keep your video call partner from virtually intruding on your personal space.

Bailenson's bottom line: "I'm thankful that companies like Zoom are making videoconferencing easy. I just want more thoughtfulness on the effects that design decisions have on social interaction and well-being." ▯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Rethinking the Everest Selfie

PHOTO: MATT IRVING

I NEVER IMAGINED I would appear in a Mount Everest photo—but here I am (at left) wrapped in a down suit and oxygen mask, 400 feet below the summit.

This may sound like an unlikely admission for a professional climber who's spent the past two decades pursuing summits all over the world. Many consider a selfie from the highest point on the planet to be the ultimate trophy. To get it, more than a few people have risked everything—including life savings and relationships—and, tragically, many have died on the descent, with their precious images still locked in their cameras.

But over the years, the idea of an expedition to Everest repelled me. The mountain came to represent the opposite of everything that I loved and respected about climbing.

The first mountain I attempted to climb wasn't even a mountain. It was a 500-foot granite cliff in North Conway, New Hampshire, called Cathedral Ledge that I tackled with a buddy. We were 15 and headstrong and knew absolutely nothing about technical climbing, apart from what we had gleaned from a poster of a climber I had tacked onto my bedroom wall. That craggy-jawed man had a rope tied around his waist. (We didn't realize it was a vintage photo, from the days before harnesses had been invented.) So we grabbed a clothesline from my dad's toolshed and headed for the cliff. Somehow we managed to claw and scrape our way a couple hundred feet up the nearly vertical wall to the safety of a small ledge.

Sitting side by side on our airy perch, we stared out over Mount Washington Valley, watching the sun dip toward the horizon and wondering how the hell we were going to get down. That first foray into the vertical world was like a drug. The thrill of doing something most people wouldn't consider, the satisfaction of figuring out the puzzle of handholds and footholds, the soul-gripping fear of making a mistake, the discovery of the view at the top, and the bond my buddy and I shared after the experience—it all came to define the essence of what I have been seeking in the mountains ever since. It was never about a photo.

In the mid-1980s, when I first started climbing, the Everest guiding industry hadn't even been imagined yet. Only experienced climbers with long résumés of high-altitude expeditions were invited to join the elite teams that dared to ascend above 8,000 meters into the so-called Death Zone. But as I honed my skills in places like Baffin Island, Patagonia, and the Karakoram, climbing on Everest began to change.

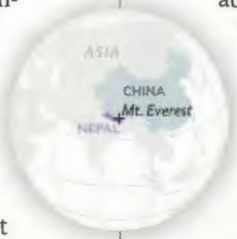
What had once been the ultimate mountaineering objective became the focus of a lucrative commercial guiding industry. Now anyone who could afford the hefty price tag could attempt to scale the world's tallest peak. The highly publicized deaths of eight climbers during the 1996 spring climbing season, famously documented in Jon Krakauer's book *Into Thin Air,* actually fueled the frenzy. Over the years, the crowds at Base Camp grew, leaving behind tons of trash. Whenever I gave talks about

FOR YEARS I THOUGHT MOUNT EVEREST WAS A TRAIN WRECK OF AMATEURS AND EGOS. THEN I WENT THERE AND WAS SURPRISED AT WHAT I FOUND.

BY **MARK SYNNOTT**

climbing expeditions, invariably someone would ask whether I'd climbed Everest. My answer was always the same: not interested.

That's probably where my personal Everest story would have ended, were it not for an old friend and his obsession with one of mountaineering's greatest mysteries. In 1999 Thom Pollard was a cameraman on the expedition that found the remains of George Mallory, the legendary British climber who disappeared while attempting to be the first to climb Everest. Mallory and his young partner, Sandy Irvine, were last seen high on the Northeast Ridge, going strong for the summit. Then they vanished into the clouds. Ever since, the mountaineering world has wondered whether they might have reached the top in 1924—nearly 30 years before Edmund Hillary and Tenzing Norgay. Irvine—and the Kodak camera he likely carried—had never been found. That's how I found myself, on assignment for this magazine, searching for a long-lost climber—and, just maybe, history's first Everest summit selfie.



As I wrote in last July's issue, our expedition didn't find the camera, but it did cause me to reconsider Mount Everest. As I packed for Tibet, I expected that our state-of-the-art equipment and bottled oxygen would make the climb manageable, perhaps easy. It's just a walk-up, I told myself. Wrong. When this photo was taken, I was more exhausted than I'd ever been on any expedition—and I was fighting the urge to throw up. Along the way, I continuously tipped my hat, not just to Mallory and Irvine—who climbed wearing tweed suits and hobnailed boots—but to anyone who has the drive to push himself or herself up this route.

While I did witness the crowds of inexperienced climbers clogging the fixed lines, the trash dumps, and the government mismanagement on both sides, I found the other climbers to be much more than just self-centered tourists. Over endless cups of tea in various camps, we shared route information, weather forecasts, and family photos—all united around common goals. And the feeling of solidarity I felt with this group was as strong as anything I had ever experienced before in the mountains.

The typical paying client on Everest, I realized, is more likely to be a scrappy dreamer who has scrimped and saved for the chance to do something remarkable than a fat-cat CEO with an outsize ego. Contrary to popular belief, most Everest climbers are looking for the same sublime experience that I first found on Cathedral Ledge as a kid. It was hard not to admire their grit and to revel in our common humanity—as passionate and dangerously flawed as it might be.

This spring it's unclear how many, if any, climbers will gather in the base camps in Nepal and Tibet to begin the process of climbing the world's highest peak. But eventually they'll be back.

I went to Everest seeking physical artifacts of Irvine. But in the end, I found something perhaps more elusive: the spirit that Irvine and Mallory shared. It was hiding in plain sight, right where it has always been: inside the intrepid souls who risk so much to follow in storied adventurers' footsteps up Mount Everest. □

Mark Synnott wrote about searching for Sandy Irvine's camera in the July 2020 issue. His book *The Third Pole: Mystery, Obsession, and Death on Everest* will be published this spring by Dutton.

A photo taken with a drone (operated by photographer Renan Ozturk) shows the North Col camp on Mount Everest.

PHOTO: RENAN OZTURK. NGM MAPS

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THE MISPLACED AFFECTION OF A BEETLE FOR A BOTTLE

BY **EVA VAN DEN BERG**

IT WAS SPRINGTIME near Dongara, in Western Australia, and biologists Darryl Gwynne and David Rentz were conducting field research on insect species. At one spot by the road was a discarded beer bottle—the squat variety known in Australia as a stubbie, with bands of small bumps adorning its brown glass. And clinging to the empty bottle was an insect: a member of the jewel beetle family bent on copulation, attempting to insert its sexual organ into the bottle.

Since Gwynne and Rentz witnessed that in 1981, other observers have documented the behavior on social media. It's identified as an example of supernormal stimuli, in which a stimulus elicits an exaggerated response. In this case, the provocateur is the stubbie: The male beetle apparently mistakes the bottle for a giant female of its species, which has similar coloring and bumps on its shell. Males lose not only their minds for this gleaming love goddess but sometimes their lives. A beetle feverishly mounting the bottle can be attacked by ants that, in the words of Gwynne and Rentz, may bite into "the soft portions of his everted genitalia."

For this discovery the biologists received an Ig Nobel Prize, the tongue-in-cheek award that recognizes scientific research projects that "make you laugh, then think." □

HABITAT/REGION

The jewel beetle inhabits arid and semiarid zones of Australia, in the states of Queensland, New South Wales, South Australia, and Western Australia.

OTHER FACTS

The jewel beetle family Buprestidae comprises some 15,000 species, including an estimated 1,500 found in Australia. The one Gwynne and Rentz studied is from the genus *Julodimorpha;* its species designation remains a matter of debate. The beetles can grow to more than an inch and a half long, and females are larger than males. The male jewel beetles can fly, but the females can't.

At Shark Bay, Western Australia, male jewel beetles exhibit their species' apparent "supernormal" drive to mate with a beer bottle.

PHOTO: JIRI LOCHMAN, NATURE PICTURE LIBRARY

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DIPLOMACY, SIP BY SIP

PHOTOGRAPH BY REBECCA HALE

1. *Kensui*
After water is used to clean the matcha cup, or teacup, at the start of the ceremony, it is poured into this.

2. *Sensu*
Tea masters paint themes or concepts for their ceremony in Japanese characters on a small decorative fan.

3. *Chashaku*
A box holds a thin bamboo spoon for putting matcha into the cup.

4. *Kobukusa*
Because natural bamboo is very delicate, it's gently cleaned with this cloth instead of with water.

5. *Natsume*
A box holds matcha grown in Kyoto. Each ceremony master has a favorite type of the ground green tea.

6. Candies
Before guests drink tea, the host serves them treats.

7. Kimono
Sobin Koizumi, a tea ceremony master from Kyoto, is traditionally attired.

8. *Kobukusa*
A special textile is required for passing the cup of tea to the guest.

9. Matcha bowl and whisk
A bamboo whisk is used to mix the matcha with hot water. After no more than 10 seconds, tea is served.

10. *Kama*
An iron pot is set on charcoal to boil water. Some pots are hundreds of years old, passed down by generations of tea masters.

11. *Hishaku*
A bamboo ladle is used to transfer hot water from pot to cup.

12. *Futaoki*
A small stand props up the ladle between uses.

WHEN AKIKO KAWAI returned to Japan after studying political management in Washington, D.C., she was convinced that the harsh realm of campaigning and lobbying could learn from the world of tea. "The core spirit of Japanese tea culture is harmony," Kawai says. In 2017 she founded Sakura Cha Meet, a global NGO specializing in "tea diplomacy," a concept dating to World War II that aims to bridge political divides by the act of sharing a cup of tea. Since then, she's hosted ceremonies from Texas to Israel—and online, to accommodate social distancing in the time of COVID-19. –NINA STROCHLIC

WILD ALASKA

America's least visited national park, Gates of the Arctic is a rugged

DRAWING FEWER THAN 10,000 visitors a year—just a fraction of those at other U.S. national parks—this remote landscape lies in the Alaska interior, entirely above the Arctic Circle. Its more than 8.4 million acres give intrepid adventurers plenty of room to roam.

GETTING AROUND

Established in 1980 to protect undeveloped land—including part of the Brooks Range—and subsistence use by Indigenous people, Gates of the Arctic National Park challenges even the hardiest of travelers. Since there are no roads, most visitors fly from the communities of Bettles, Coldfoot, or Anaktuvuk Pass, then journey on foot or by rivercraft, skis, or dogsled. Those without extensive backcountry experience should consider a guided trip.

NATURAL WONDERS

The park's dramatic vistas shelter a wide variety of animals. From May through July, the constant sunlight means endless viewing opportunities.

- Photographers marvel at the craggy ridges of the Arrigetch Peaks in the Brooks Range.
- Birders have reported more than 145 species, including the northern goshawk, short-eared owl, and arctic warbler.
- Traveling down the Noatak River offers a good chance to see musk oxen, brown bears, caribou, and the 8,276-foot Mount Igikpak.

NATIVE CULTURE

Anaktuvuk Pass is the only gateway town within the park's borders. But the village is more than just a starting point for adventure; it's a place to learn about the people who have lived off these lands for thousands of years. Home to the formerly nomadic Nunamiut people, the village features a museum that tells the story of their continued subsistence lifestyle, which depends heavily on the caribou. The caribou herd is now threatened by climate change and a planned mining road.

'THE MORE HEARTBEATS I SPEND WALKING THE TUNDRA AND FLOATING THE RIVERS, THE MORE I AM TRANSFORMED.'

—*Kiliii Yüyan*

expanse of mountains and rivers.

BY THE NUMBERS

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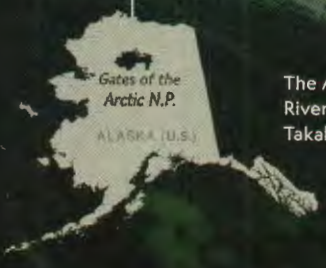
ESTABLISHED TRAILS IN THE PARK

45

AVERAGE ANNUAL SNOWFALL, IN INCHES

343

POPULATION OF ANAKTUVUK PASS



The Alatna River flows past Takahula Lake.

BY **JENNA SCHNUER** PHOTOGRAPH BY **KILIII YÜYAN**

NGM MAPS

At M.L. Ramnarain Perfumers in Kannauj, India, freshly picked roses are used to make heady botanical scents called attar.

A PERFUMED HISTORY

IN A QUEST FOR 'LIQUID GOLD,' GENERATIONS OF CRAFTSPEOPLE IN INDIA HAVE BECOME AROMA ALCHEMISTS.

BY **RACHNA SACHASINH**

LONG BEFORE SUNRISE Tegh Singh arrives at his flower farm on the banks of the Ganges. He circles the rose shrubs, plucks blossoms at peak bouquet, and tosses the pink petals into a jute sack slung over his shoulder. By the time the first rays of sunlight skim across the river, 35-year-old Singh is on his motorcycle, ferrying his harvest to the small city of Kannauj, known as the perfume capital of India.

For more than 400 years, and through time-tested distillation methods, Kannauj has been crafting oil-based botanical perfumes called attar. Sought after by Mughal royals—as well as everyday folk—in ancient India's fragrance-obsessed culture, attar has recently awakened a new generation to the allure of its sensual scents.

Unlike modern perfumes, which have alcohol as a carrier—because it's inexpensive, neutral, and easily diffused—attars traditionally use sandalwood oil, making them unctuous and highly absorptive. The scent of a droplet lingers pleasantly on the skin, sometimes for days. Equally enchanting to men and women, attars strike intense floral, woodsy, musky, smoky, or grassy notes. Attars for cold seasons can be warming, with scents of clove, cardamom, and saffron. In warmer seasons, attars can bring cooling fragrances of jasmine, vetiver, and marigold.

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YETI BAGS

Kannauj produces these, as well as the enigmatic *mitti* attar, which evokes the scent of earth after a rainfall thanks to baked alluvial clay in the distillation. *Shamama,* another coveted invention, is a distilled blend of 40 or more flowers, herbs, and resins that takes days to make and months to age. Some perfume houses in Europe use these attars—rose, vetiver, jasmine, and others—as a layer, a compelling chord in the composition of modern perfumery.

In the narrow lanes of Bara Bazaar, the city's main market, shops are crammed with glass bottles holding attar and *ruh,* or essential oil, each smelling better than the last. Men sit cross-legged on cushioned floor mats, sniffing vials and dabbing extraordinarily long perfumed cotton swabs behind their ears. Presiding over this age-old commerce is the attar *sazh,* or perfumer, conjuring and enticing with the aura of an imperial alchemist.

"The world's best perfumers have walked through these narrow lanes, making their way through mud and cow dung to get their hands on Kannauj attar. There is really nothing like it," says Pranjal Kapoor, the fifth-generation partner at M.L. Ramnarain Perfumers, one of the traditional distillers still operating here.

Tegh Singh arrives and unloads his blossoms in Kapoor's godown, an open-air courtyard that serves as the distillery. Ram Singh, Kapoor's master attar craftsman, scoops the petals into a copper still and tops it with water. Before fastening the lid, Ram Singh packs the rim with a clay-and-cotton mash, which hardens and creates a formidable seal. When the flowery concoction begins to simmer, steam travels from the still, via a bamboo reed, into a copper pot holding sandalwood oil, which readily imbibes the rose-saturated vapor.

During the five to six hours it takes for Tegh Singh's roses to become attar, Ram Singh moves between the still and the pot, testing the water temperature and listening to the hiss of steam to intuit whether to feed more wood into the fire. "I've been doing this since I was a boy," says the 50-year-old Ram Singh.

To achieve the desired potency, the process is repeated the next day, with a new batch of rose petals. Once this is done, the rose attar is aged for several months in a camel-skin bottle, which wicks moisture. The finished rose attar is akin to liquid gold. One kilo (2.2 pounds) can fetch up to $3,000.

Today most Kannauj attar ends up in the Middle East and among regional Muslim communities in India. In Old Delhi's Chandni Chowk market, built in the 17th century by Mughal emperor Shah Jahan, Gulab Singh Johrimal is a longtime institution that now carries both attar and modern fragrances. It's almost always full of Muslim men in search of attar to scent themselves before Friday prayers and festivals such as Eid. But local markets aren't enough to sustain Kannauj's distilleries, and many have had to close or shift to making facsimiles of Western perfumes.

PRESIDING OVER THIS AGE-OLD COMMERCE IS THE ATTAR *SAZH*, OR PERFUMER, CONJURING AND ENTICING WITH THE AURA OF AN IMPERIAL ALCHEMIST.

Nonetheless, Kapoor is optimistic. He spends much of his time courting top international perfume houses, touting the traditions of attar and the terroir of Kannauj botanicals. "Western tastes are shifting east," he says. "Typically, [the West] prefers light, citrusy notes, but these days you see the big daddies like Dior, Hermès, and of course, the Middle Eastern perfume houses going for gilded scents like rose and shamama."

Perhaps attar's most prominent global ambassador is Jahnvi Lakhota Nandan, born in the scent-loving city of Lucknow, who trained as a master perfumer in Europe for seven years before opening The Perfume Library in Goa and Paris. Nandan's distillations are equal parts poetry, eccentricity, and science. Each year she creates one, perhaps two, new scents, and attar is an important part of her repertoire.

"Attar speaks to the soul. All the fire and smoke in a small space can seem apocalyptic, but it's also authentic and beautiful," she says. "You cannot re-create this in a lab in Europe." □

Based in Thailand and Laos, **Rachna Sachasinh** writes about culture and travel throughout Asia. Photographers **Tuul and Bruno Morandi** live in Paris and have roamed the globe for their projects.

In the Bottle

At a shop in Jaipur, crystal bottles show off high-quality attar from Kannauj. Built atop alluvial soil, near the Ganges River, Kannauj is well suited to cultivating fragrant plants, such as jasmine and rose, that are distilled into varieties of perfume.

PHOTOS: TUUL AND BRUNO MORANDI. NGM MAPS

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FEATURES

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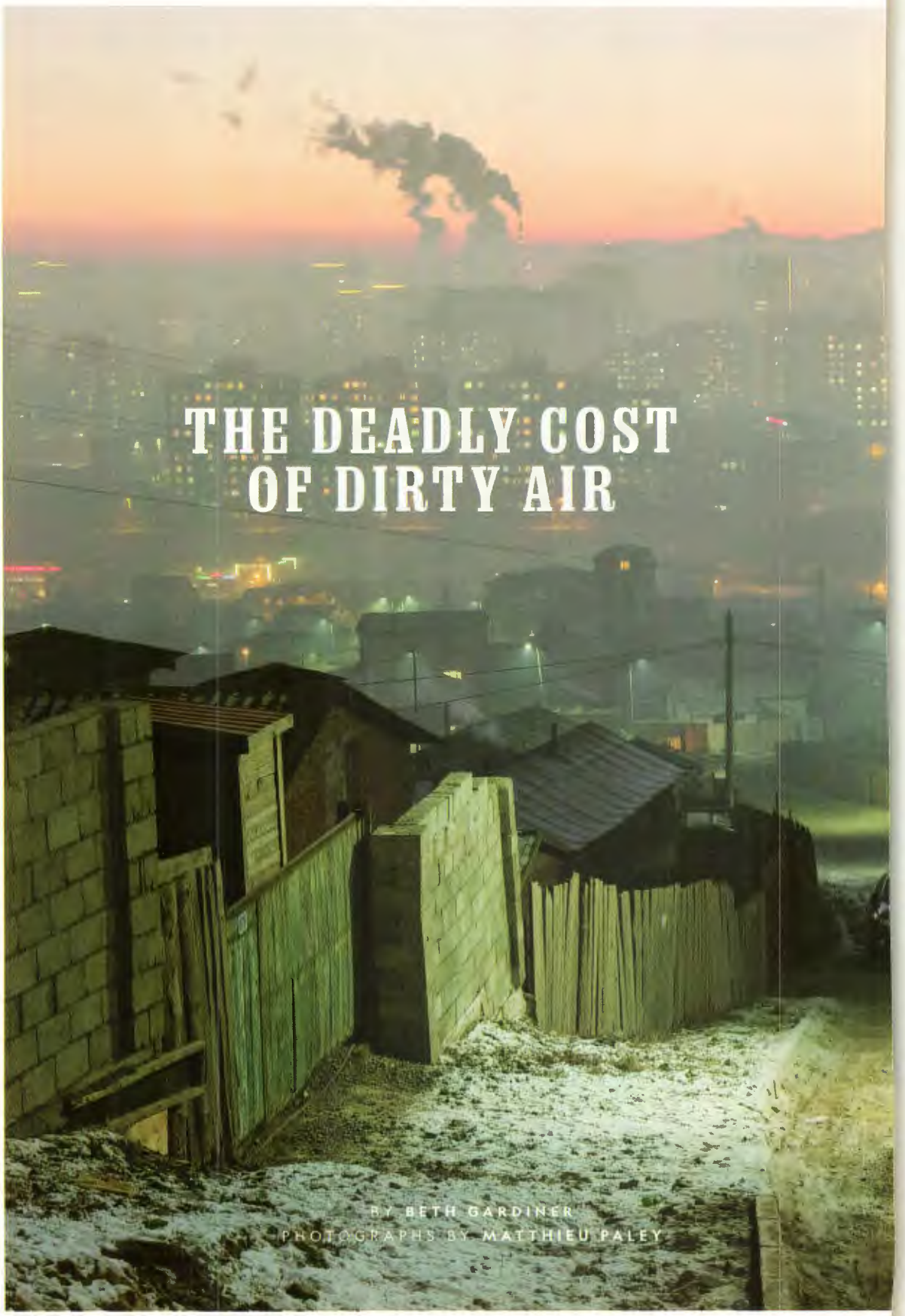
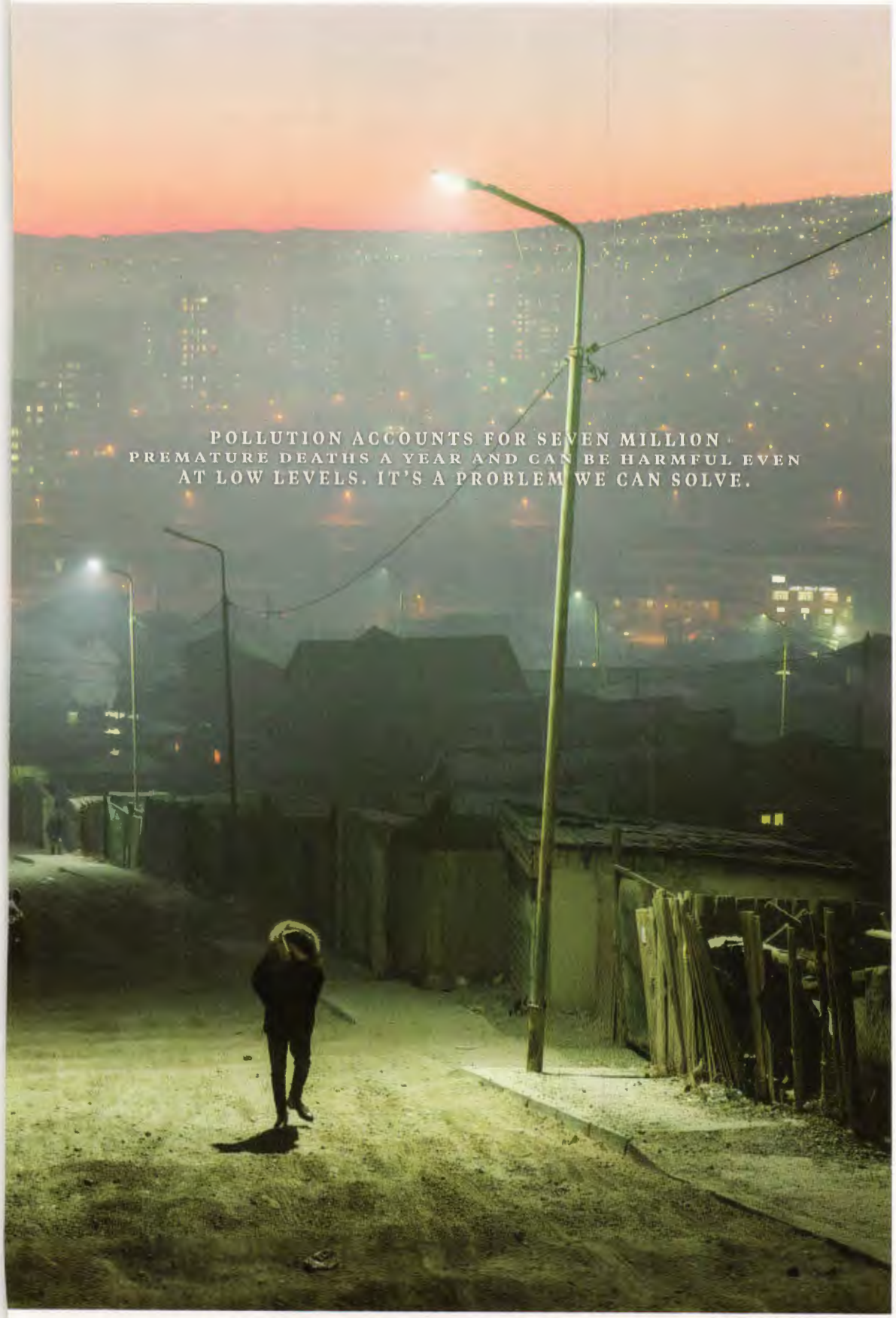
'FLORIDA STILL HAS WILDERNESS AND LARGE CATS, SOME RESILIENT ENOUGH TO LIVE UNSEEN ALONG THE FRINGES OF THE EXPANDING SUBURBS.'

PHOTO: CARLTON WARD, JR.



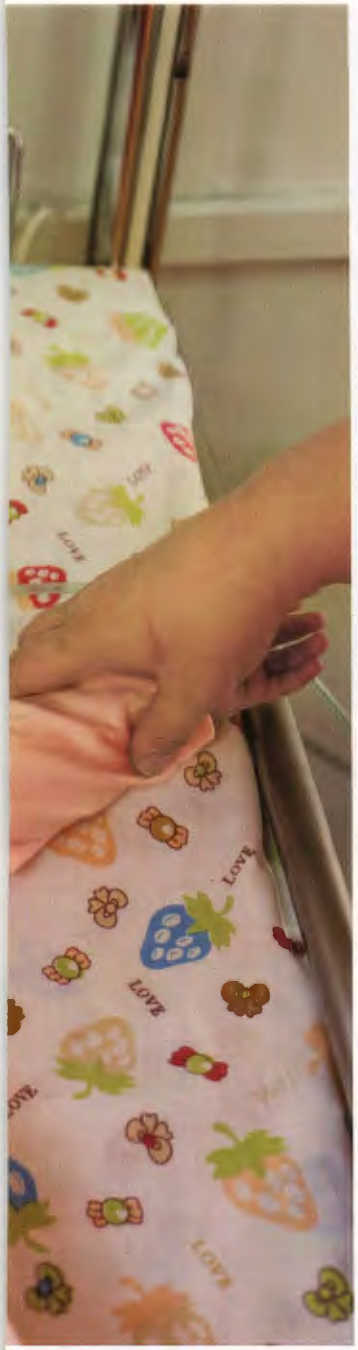
THE DEADLY COST OF DIRTY AIR

BY BETH GARDINER
PHOTOGRAPHS BY MATTHIEU PALEY


POLLUTION ACCOUNTS FOR SEVEN MILLION
PREMATURE DEATHS A YEAR AND CAN BE HARMFUL EVEN
AT LOW LEVELS. IT'S A PROBLEM WE CAN SOLVE.

A two-year-old girl is treated in a hospital specializing in pneumonia and lung disease in Ulaanbaatar, Mongolia. On her forehead is a smudge of coal ash applied by her mother to ward off evil spirits. But coal burning is the reason that air pollution here is among the world's worst. Each winter, breathing problems spike among residents, particularly children, stretching hospitals far beyond capacity.

PREVIOUS PHOTO
Ulaanbaatar's Dari Ekh neighborhood is crowded with migrants from the countryside, nomadic herders who come to the capital seeking education and jobs. Living in simple houses or round tents called *gers,* with inadequate or no electricity, they burn coal to keep warm through the harsh winters. One study found that children in the capital had 40 percent lower lung function than rural kids—a red flag for long-term health problems.



WHEN COVID-19 began tearing around the globe, Francesca Dominici suspected air pollution was increasing the death toll. It was the logical conclusion of everything scientists knew about dirty air and everything they were learning about the novel coronavirus. People in polluted places are more likely to have chronic illnesses, and such patients are the most vulnerable to COVID-19. What's more, air pollution can weaken the immune system and inflame the airways, leaving the body less able to fight off a respiratory virus.

Many experts saw the possible connection, but Dominici, a biostatistics professor at the Harvard T.H. Chan School of Public Health, was especially well equipped to test it. She and her colleagues have spent years creating an extraordinary data platform, one that aligns information on the health of tens of millions of Americans with a day-by-day summary of the air they've been breathing since 2000. Dominici explained it to me last summer on a video call from her home in Cambridge, Massachusetts. Her pandemic puppy, a black Lab, squirmed on her lap. In London, where I sat in my home office, the brief respite in traffic provided by the initial lockdown had ended, and diesel fumes once again clouded the air.

Every year, Dominici told me, she purchases granular (but anonymized) information on each of the roughly 60 million

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COAL AND ITS CONSEQUENCES ARE EVERYWHERE IN ULAANBAATAR.

TOP LEFT

A man sweeps the floor at a coal-processing plant, where raw coal is made into briquettes for home stoves.

TOP RIGHT

Coal-burning power plants such as this are another source of pollution—a menace to health and the climate.

BOTTOM LEFT

A child's chest x-ray at a hospital in Ulaanbaatar is reviewed for signs of pneumonia. Pollution is a risk factor for that illness.

BOTTOM RIGHT

An anti-pollution activist stands in Sühbaatar Square, outside the parliament building. Mongolia's government has done little to develop clean energy.

Vendors shoveling raw coal used to be a common sight along roads in Ulaanbaatar; a single family might easily burn three tons each winter. The government has now banned raw coal in favor of briquettes—but air pollution remains dangerously high.

YANKS

older Americans enrolled in Medicare—age, gender, race, zip code, and the dates and diagnostic codes for all deaths and hospitalizations. That's half the data platform. The other half is an achievement in itself. Led by Dominici and Harvard epidemiologist Joel Schwartz, dozens of scientists first divided the United States into a grid of one-kilometer-wide (.62-mile) squares. Then they trained a machine learning program to calculate daily pollutant levels, over 17 years, in each square—even if it didn't have a pollution monitor in it.

With those twin troves of data, Dominici and her colleagues could for the first time study the effects of air pollution in every corner of the U.S. It led them to some troubling conclusions. In a 2017 study they found that even in places where the air met national standards, pollution was linked to higher death rates. That means "the standard is not safe," Dominici explained.

Two years later the team reported that hospitalizations for a host of ailments—including conditions such as kidney failure and septicemia, whose link to pollution had been little examined—went up whenever pollution rose. Those findings added to a mountain of evidence demonstrating the dangers of PM2.5, or particulate matter smaller than 2.5 micrometers, about a 30th the width of a human hair. Some of those particles—of soot, for example—can cross into the bloodstream. Scientists have found them, including even tinier "ultrafine" particles, in the heart, brain, and placenta.

When the pandemic hit, Dominici and her team quickly decided to cross-reference nationwide air quality data against Johns Hopkins University's county-by-county tally of COVID-19 deaths. Sure enough, viral death rates were higher in places with more PM2.5—the places where decades of exposure to bad air had primed people's bodies to be susceptible to the coronavirus. Worldwide, the team reported in December, particle pollution accounted for 15 percent of COVID-19 deaths. In badly polluted countries in East Asia, it was 27 percent.

Many outside the scientific world were shocked. The finding made headlines. "To me, it was not surprising at all," Dominici said. "It made perfect sense." She already knew what much of the public doesn't—that dirty air ends far more lives, and with far greater regularity, than the novel coronavirus.

Globally, air pollution accounts for about seven million premature deaths a year, according to the World Health Organization (WHO)—more than twice as many as alcohol consumption and more than five times as many as traffic accidents. (Some recent research puts pollution's toll far higher than the WHO estimate.) A majority of those deaths are caused by outdoor air pollution; the rest are attributable primarily to smoke from indoor cookstoves. Most of the deaths occur in developing countries—China and India alone account for about half—but air pollution remains a significant killer in developed ones too. The World Bank puts the global economic cost at more than five trillion dollars annually.

VIRAL DEATH RATES ARE HIGHER IN PLACES WITH THE MOST PARTICLE POLLUTION.

In the United States, 50 years after Congress passed the Clean Air Act, more than 45 percent of Americans still breathe unhealthy air, according to the American Lung Association. It still causes more than 60,000 premature deaths annually—not counting the many thousands who have died because it made them more vulnerable to COVID-19. Pollution is a hidden killer; it doesn't get listed on death certificates. Perhaps this year, Dominici said when we spoke, its intersection with frightening new threats—a raging virus and wildfires—would help us recognize the damage it has been doing all along.

But in December, when the U.S. Environmental Protection Agency formally decided not to tighten the national air quality standards for PM2.5, maintaining them at their current levels, it ignored Dominici's research and that of its own scientists. They had calculated that lowering the annual standard by 25 percent would save 12,000 lives a year.

AIR POLLUTION'S BRUTAL bottom line—the more there is, the shorter the lives of those who breathe it—was established most definitively by a landmark 1993 project known as the "Six Cities" study. People in the most polluted of six small American cities analyzed by Harvard researchers were 26 percent more likely to die prematurely than those in the cleanest of the six. Pollution was taking about two years off their life spans.

"It was very, very surprising. And in fact it was such a big effect, we didn't believe it," lead author Douglas Dockery, now retired, told me. But another long-term data set from the American Cancer Society soon confirmed it.

Since then, further research has revealed two more essential truths about air pollution: It's harmful at much lower levels than once thought, and in many more ways. The sheer variety stunned Dean Schraufnagel, a pulmonary medicine professor at the University of Illinois at Chicago, when he led a panel in 2018 that reviewed and summarized decades of research.

Dirty air, his committee reported, affects nearly all the body's essential systems. It may cause about 20 percent of all deaths from strokes and coronary artery disease, triggering heart attacks and arrhythmias, congestive heart failure and high blood pressure. It's linked to lung, bladder, colon, kidney, and stomach cancers and to childhood leukemia. It harms kids' cognitive development and raises older people's risk of contracting dementia or dying of Parkinson's disease. It's been credibly tied to diabetes, obesity, osteoporosis, decreased fertility, miscarriage, mood disorders, sleep apnea—the list goes on.

"The breadth of it was the most surprising," Schraufnagel said.

There's a more hopeful flip side: Cleaner air brings better health. Since the Clean Air Act of 1970, a 77 percent drop in pollution has lengthened millions of Americans' lives. The 1990 amendments to the law prevented 230,000 deaths in 2020 alone, according to an EPA estimate.

Elsewhere in the world, the air is far worse. Photographer Matthieu Paley and I visited Ulaanbaatar, Mongolia, one of the most polluted capitals on Earth—especially in the punishing winter, when coal becomes a survival tool. It's burned by the ton in the city's power plants and by the bagful in the *gers* (Mongolian yurts) that house poor migrants from the countryside.

"I no longer know what a healthy lung sounds like," said Ganjargal Demberel, a doctor who makes house calls in one such neighborhood. "Everybody has bronchitis or some other problem, especially during winter."

WORLDWIDE, PARTICLE POLLUTION ACCOUNTED FOR 15 PERCENT OF COVID-19 DEATHS.

Even environmentally progressive Europeans live with pollution significantly worse than what Americans endure. In eastern and central Europe, health- and climate-wrecking coal smoke still pours from home chimneys and power plants. In London, where I've lived for 20 years, coal smoke once blanketed the city in deadly pea soup fogs, but mercifully, those days ended long before I arrived. Instead, the country and its continental neighbors now suffer the effects of another toxic fuel: diesel.

Dirtier than gasoline, diesel's long been popular in Europe because it offers vehicles slightly better mileage. Paris and Barcelona, Rome and Frankfurt—their busy thoroughfares are clouded with fumes like London's, air so thick it covers your teeth with a layer of grit. I feel the difference every time I return to New York and gulp air noticeably cleaner than London's. Back in Britain, I worry what the fumes may be doing to my teenage daughter, whose lungs are still growing and vulnerable.

The root of Europe's air quality problem is not just a particular fuel but also the political and regulatory failures that let auto manufacturers get away with selling cars whose emissions shattered legal limits. In 2015 the public learned that Volkswagen had programmed 11 million diesel cars with "defeat devices"—software that activated pollution controls during

tests but turned them off the rest of the time. U.S. authorities forced the company to spend billions compensating customers and fixing or buying back vehicles. Europe, however, has allowed 51 million cars and vans (from a variety of manufacturers) to stay on the road with nitrogen dioxide emissions three or more times the limit, according to the advocacy group Transport & Environment. That excess pollution causes nearly 7,000 premature deaths annually, one study found.

Instead of forcing manufacturers to bring cars into compliance, Europe is mostly leaving cities to tackle the problem. Across the continent, local governments are banning the dirtiest vehicles or penalizing their owners. It's one step toward cleaner air—and there are signs that such measures are pushing drivers away from diesel—but the patchwork efforts aren't nearly as effective as higher-level action could be.

Diesel and coal aren't the only things fouling the air, of course, in Europe or elsewhere. Woodsmoke from fireplaces or stoves, thick with PM2.5, is a growing problem. Last year's lockdowns gave scientists an unexpected chance to see what happens when some sources of pollution temporarily cease. As the virus ravaged northern Italy in the spring, Valentina Bosetti and Massimo Tavoni, married economists at the RFF-CMCC European Institute on Economics and the Environment in Milan, were stuck at home with their three sons.

"Instead of killing each other and killing the kids, at some point we thought, OK, there is this data," Bosetti told me.

Despite transportation and industry being all but halted, the couple found that air quality hadn't improved as much as many locals thought. "Newspapers were saying, Blue sky, everything is perfect," Bosetti said. "Not really." At monitors away from roads or factories, PM2.5 levels fell only 16 percent, nitrogen dioxide only 33 percent. One big sector, it turned out, was still polluting while people stayed home: agriculture.

Modern industrial farming is a major polluter. One study ranked agriculture as the biggest single PM2.5 source in Europe, the eastern U.S., Russia, and East Asia. Huge amounts of manure, as well as chemical fertilizers, give off ammonia, which reacts with other pollutants in the air to create the tiny particles. Scientists have long understood that, but Bosetti hopes the vivid real-world demonstration may help generate political will to take action.

CHINA STILL LEADS the world in air pollution deaths, but it has made great strides lately in cleaning its skies—whereas India's response has been mostly ineffectual. Indian cities hold nine of the top 10 spots in the WHO database of PM2.5 levels. The human cost is horrific: nearly 1.7 million premature deaths a year.

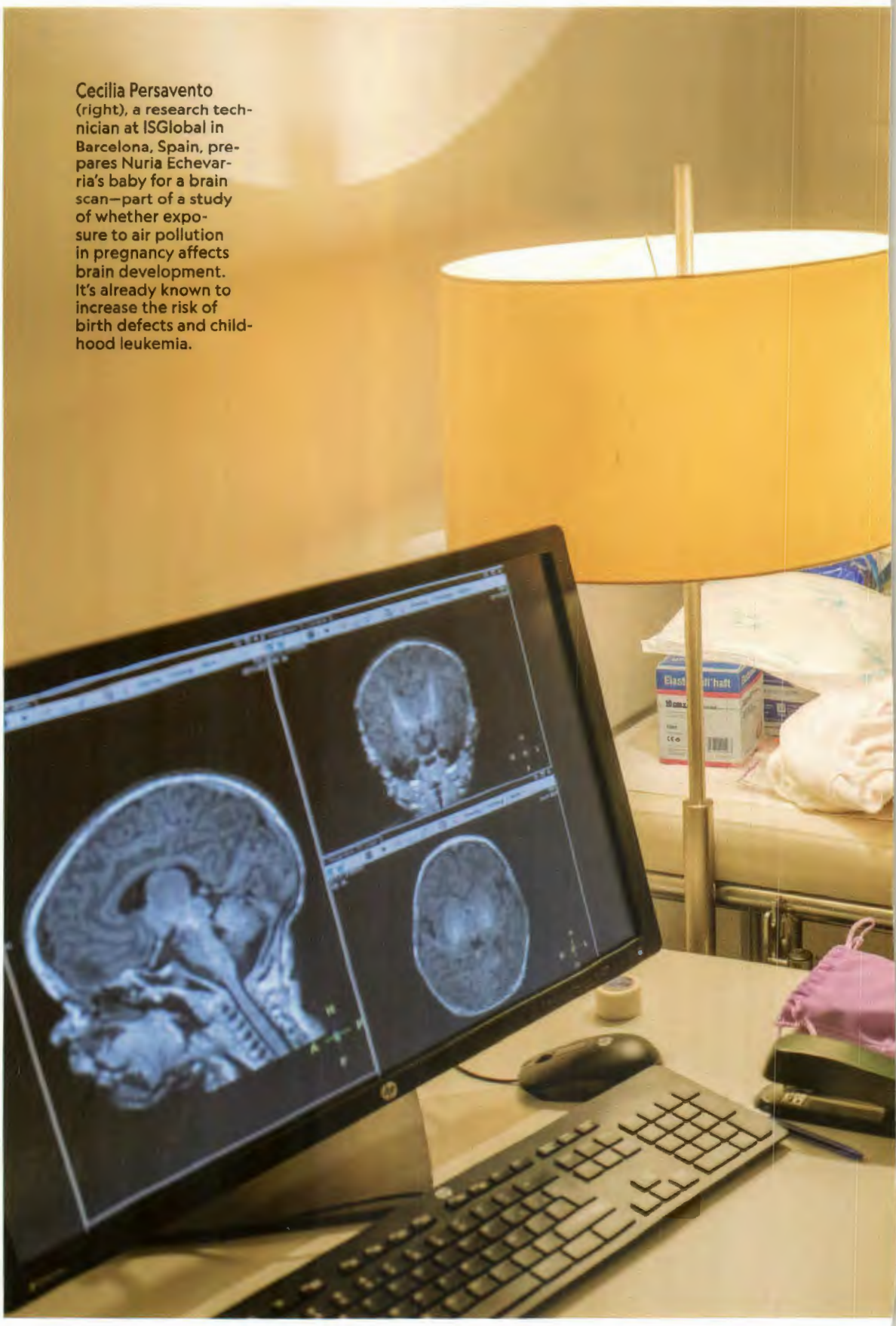
India's pollution floats from a dizzying variety of sources. Trash fires smolder in streets where garbage goes uncollected. Frequent power outages mean diesel generators are common. Villagers and the urban homeless burn wood, dung, and even plastic to cook and keep warm. Every autumn, clouds of smoke drift over Delhi from Punjab and Haryana, where farmers set fields alight to clear them after harvest.

"It's like living in a gas chamber," Delhi writer and activist Jyoti Pande Lavakare told me. In the worst months, whenever she goes outside, "I get a dull pollution headache. My daughter gets a headache too; she feels a little nauseous sometimes. Your eyes will water." Americans got a brief taste of Delhi's typical pollution last fall, when parts of the West were engulfed by wildfire smoke.

Lavakare used to live in California, but in 2009 she and her husband moved their family home to be near their parents. She was surprised

In London, where Ella Roberta Adoo Kissi-Debrah (above) lived steps from a busy thoroughfare, diesel is a main pollution source. Ella had severe asthma and often was hospitalized during pollution spikes. She died of her illness in 2013, at age nine. "I miss her touching my face," says Ella's mother, Rosamund (right). Once a teacher, now an activist, she fought for years to raise awareness of air pollution by getting it added to Ella's death certificate. In December 2020 a coroner finally ruled in her favor.

HOLLIE ADAMS, GETTY IMAGES (ABOVE) SERENA BROWN (RIGHT)



Cecilia Persavento (right), a research technician at ISGlobal in Barcelona, Spain, prepares Nuria Echevarria's baby for a brain scan—part of a study of whether exposure to air pollution in pregnancy affects brain development. It's already known to increase the risk of birth defects and childhood leukemia.

HOW THE U.S. CLEARED THE AIR

50 YEARS AGO THE CLEAN AIR ACT FOLLOWED THE SCIENCE—AND BECAME A MODEL FOR THE WORLD.

LONGTIME RESIDENTS of Los Angeles remember the days when the mountains around the city were all but invisible. Today they're a central part of its craggy beauty.

It's not just Southern California. Thanks to the Clean Air Act of 1970, air across the United States has gotten 77 percent cleaner—even as the population, the economy, and the number of cars on the road have grown. That improvement has lengthened millions of lives, saved trillions of dollars, and made the country a global air pollution success story.

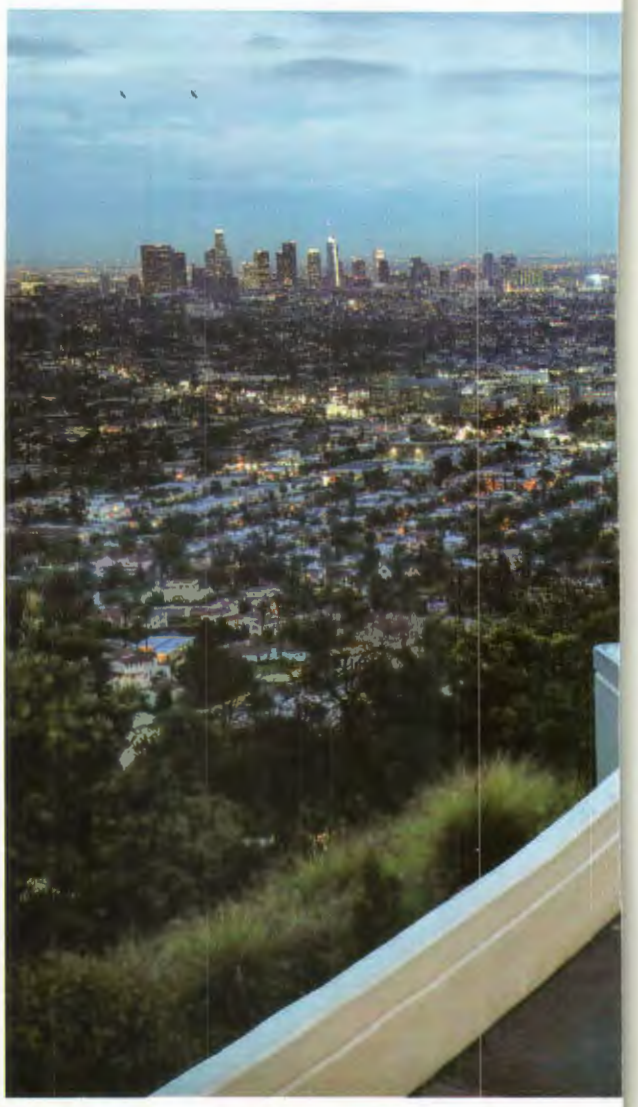
The landmark law was a bipartisan achievement, winning unanimous Senate approval and passing the House of Representatives with just one "no" vote.

Its success stems from its focus on scientific evidence, accountability, and ambitious, health-based goals.

"The Clean Air Act remains the most powerful public health law enacted in the 20th century in the United States," said Paul Billings of the American Lung Association.

Among its provisions were a requirement that carmakers reduce tailpipe pollution by 90 percent. Today's cars are 99 percent cleaner than pre-1970 models. And it all came at a bargain: Researchers have estimated the law's overall benefits have been more than 40 times as great as its cost. That success is a reminder of how capable we are of cleaning up pollution, and of solving problems that seem intractable, when our political leaders are prepared to act on scientific evidence.

But it's still a work in progress, said Mustafa Santiago Ali, a vice president of the National Wildlife Federation: "I hope we'll come to a point in our history, sometime soon, where not only do we understand the value of [the act], but we're willing to do the hard work of enhancing it." **—BETH GARDINER**

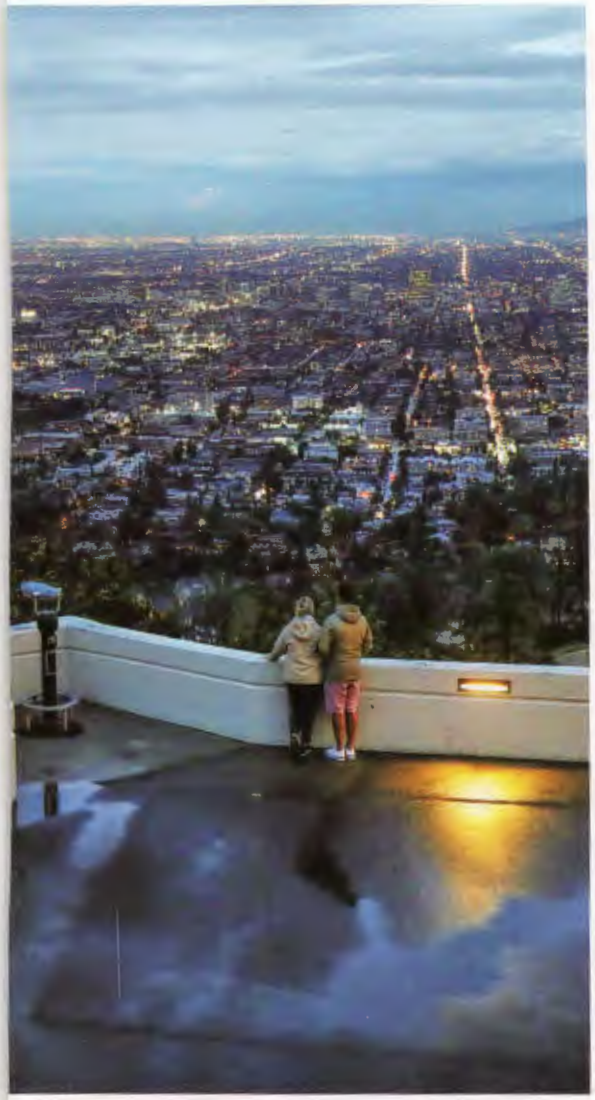


ABOVE
From the Griffith Observatory, you can now reliably get a clear view of the Los Angeles skyline—a dramatic illustration of how much cleaner the city's air has gotten. But it's still among the nation's dirtiest.
MARIO TAMA, GETTY IMAGES

RIGHT
Smog hangs over Los Angeles in 1957. Southern California's air was so unhealthy that parents routinely kept children indoors. The sky often glowed orange. Traffic was a big part of the problem—and it still is.
UNIVERSITY OF SOUTHERN CALIFORNIA/GETTY IMAGES

HOW YOU CAN HELP

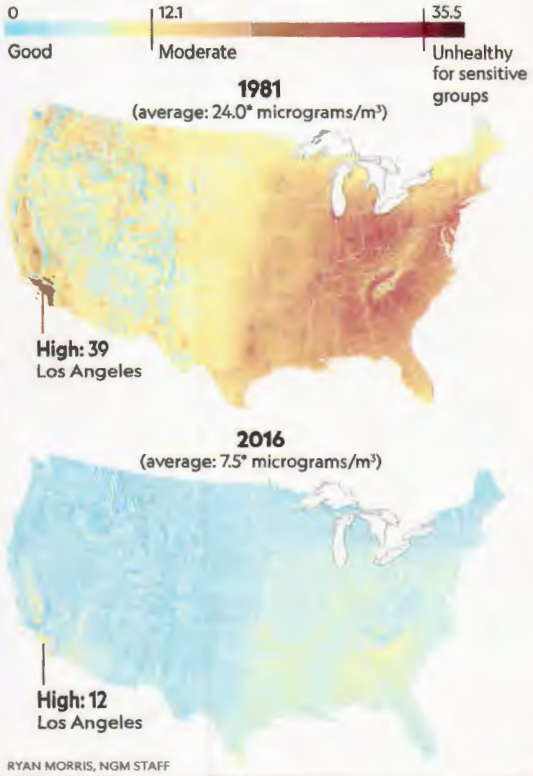
1. Walk, bike, drive an electric car—avoid burning gasoline or diesel.
2. Avoid burning other stuff, especially in cities—wood, charcoal, leaves, trash, fireworks.
3. Protect yourself from bad air: When possible, walk and bike on roads with less traffic.
4. Support leaders who vote for clean energy and tight rules on air pollution.



A CLEANER COUNTRY

Air quality in the United States has improved dramatically since the Clean Air Act was passed in 1970. Concentrations of PM2.5 (hazardous fine particles with diameters under 2.5 micrometers) have decreased broadly, thanks largely to regulations adopted under the landmark law.

PM2.5 air pollution concentration, estimated
(micrograms per cubic meter)



RYAN MORRIS, NGM STAFF
*POPULATION-WEIGHTED. LONG-TERM ESTIMATES NOT AVAILABLE FOR ALASKA AND HAWAII.
SOURCES: JUN MENG, DEPARTMENT OF PHYSICS AND ATMOSPHERIC SCIENCE, DALHOUSIE UNIVERSITY; CHI LI; RANDALL V. MARTIN; AARON VAN DONKELAAR; PERRY HYSTAD; MICHAEL BRAUER

by how much worse India's pollution had gotten. Her parents shrugged off her suggestion to install air purifiers but felt better after she bought some. Then, in 2017, her mother was diagnosed with lung cancer.

"It moved so fast," Lavakare recalled. The doctors "were like, Yeah, see where she lives? She's lived in north India all her life. This is the pollution capital of the world." She died in 2018.

By then Lavakare had co-founded an advocacy group that fought successfully for parliament to debate the issue—and even filed a human rights petition with the United Nations. She wrote a book, *Breathing Here Is Injurious to Your Health,* about her mother's death. "There's nothing we haven't tried," she told me. "Sadly, I don't think we're making much progress."

For a time in the 1990s and early 2000s, things looked hopeful in Delhi. Pushed by the Supreme Court, the city demanded that buses and its ubiquitous auto-rickshaws switch to running on compressed natural gas. But economic growth quickly outpaced all antipollution measures. The number of cars on India's roads, for example, more than quadrupled from 2001 to 2017. Brickmaking intensified to feed the construction boom—and the bricks were made in kilns that burned coal without filtering the smoke.

There has been one bright spot: A push to give rural Indians alternatives to smoky cooking fuels has cut indoor pollution and saved hundreds

In south Baltimore, Maryland, concern about pollution led Shashawnda Campbell (seated in front) and fellow youth activists in the Brooklyn and Curtis Bay neighborhoods to help defeat plans to build an incinerator nearby. Residents here already live close to other industrial polluters, including a medical waste incinerator, a chemical plant, and a landfill.
GABRIELLA DEMCZUK

of thousands of lives a year. But there's been no significant improvement in outdoor pollution for a decade, said Sarath Guttikunda, director of Urban Emissions, a research group. "We have not seen a decline of any sort in any of the cities," he told me.

Lavakare now regrets giving up her American green card. She knows her position is privileged: India's urban poor, who work or even live on the streets, breathe far worse air. It's a dynamic seen all over the world. Like the coronavirus, pollution maps onto the existing fractures in our societies. But with COVID-19, deaths "happen right away. With air pollution, it just adds on over time," Lavakare said. "It's a pandemic in slow motion."

IN THE U.S., pollution adds one more dimension to the nation's stark racial inequality. Black Americans, one study found, are exposed to about 1.5 times more PM2.5 than the overall population—and the disparity is more racial than economic.

"Rich Black Americans breathe more pollution than poor white Americans, consistently," Dominici told me. The divide is growing. "As we've been cleaning up the air in this country, we're cleaning the air mostly where whites live."

Resistance from those who suffer under that disparity is growing. In 2013, when Shashawnda Campbell was still in high school in south Baltimore, she heard that Maryland had approved plans for a new incinerator less than a mile from her school. Her reaction was immediate: "No. We don't need that. It already stinks here; it's already polluted enough."

The Brooklyn and Curtis Bay neighborhoods, where Campbell and her classmates lived, are poor, with sizable Black and Latino populations. The area was already burdened with a medical waste incinerator, a chemical plant, a landfill, and an enormous open coal pile. "It's not by accident that all these things are in this community. This is on purpose," Campbell said. A dirty facility gets put in Brooklyn or Curtis Bay "because no one else wants it. But they don't ask us if we want it."

People of color are often consigned to industrial neighborhoods by a legacy of racist mortgage restrictions. And companies build new polluting facilities in such areas because land is cheaper and residents tend to have little political sway, said George Thurston, an environmental medicine professor at New York University. "They avoid the wealthier neighborhoods where people have that power," he said. "They want to locate in places where there's less resistance."

Campbell wasn't ready to let that happen again. Calling themselves Free Your Voice, she and a group of classmates started knocking on doors and gathering signatures. "We knew we had to fight back," she recalled. It took three years, but they won. The incinerator plans were halted. "It was just so amazing to see that wow, we really did something. We made a change."

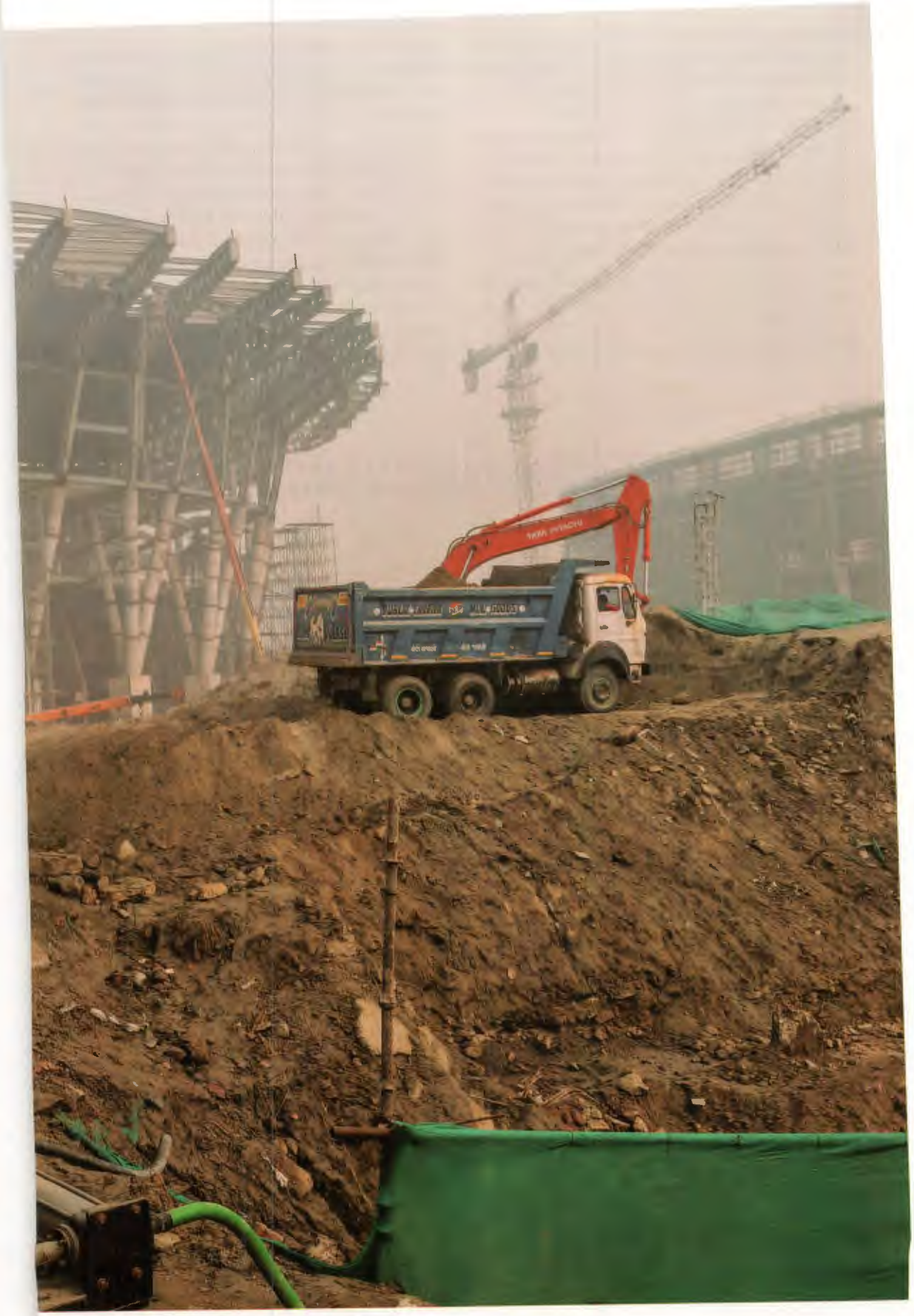
These days, Campbell goes into schools to teach kids how to combat environmental racism. At her old high school, a coach told her he couldn't field a basketball team, "because all of them have asthma. They can't run long enough." Last

Haze hangs in the air as men work on a dam project in Faridabad, India, near Delhi. The country is home to nine of the 10 most polluted cities in the world. An estimated 1.7 million Indians died prematurely in 2019 from the pollution.

SAUMYA KHANDELWAL

A machine sprays water to keep dust down at a Delhi construction site. Such dust, which can contain harmful chemicals, is a major source of the city's air pollution. Garbage and cooking fires, diesel generators, and coal-fired power plants also poison the air.

SAUMYA KHANDELWAL



summer, at Black Lives Matter marches, fellow protesters told her it had never occurred to them to connect pollution and police violence. "They're all racism in different forms," she said.

On the other side of the continent, Anthony Victoria's opponent isn't a single incinerator but the consumer economy—at least in its current form. Victoria, a young man with a goatee and round glasses, lives in California's Inland Empire, a region once known for its citrus groves. Sixty miles inland from the container ports of Los Angeles and Long Beach, it's now a warehouse hub—for Amazon, Target, Walmart—distributing products imported from China and elsewhere. "You just see row after row after row, warehouse after warehouse after warehouse," Victoria said. "You have a residential neighborhood, and you have a huge mega warehouse across the street."

The real problem is the relentless stream of trucks that rumble through neighborhoods filled with working-class people of color and immigrants. "It's the slow violence of the supply chain that really sucks the energy and the health and the livelihoods" of the communities, Victoria told me. The Center for Community Action and Environmental Justice, an advocacy group he then worked for, gave residents handheld counters to log truck traffic. Along State Route 60, an east-west freeway, they counted 1,161 in an hour.

"You can imagine the negative effects that's going to have on someone's life," Victoria went on. "Our communities are known as diesel death zones." Recently, COVID-19 has torn through some of the warehouses. "You have people that are just completely, completely in fear," Victoria said—warehouse workers "already immunocompromised because of the pollution," and now terrified they'll bring the virus home to children and parents with asthma or cancer.

Here too, there are hints of change. Victoria's group shared its truck counts with the California Air Resources Board, whose rules often lead the nation. Last year, the agency issued a new one: Manufacturers must begin phasing in zero-emissions trucks in the state by 2024, with the share of new trucks that are pollution free increasing steadily until 2035. The agency also is expanding a requirement that ships shut off their engines and plug into onshore power while docked, or else use pollution-capturing technology. Together, the truck and ship rules "are going to make a huge difference," said Joe Lyou, president of the California-based Coalition for Clean Air.

Like many measures that reduce unhealthy air pollution, the new rules also cut climate-warming carbon emissions. Both share the same cause: our dependence on fossil fuels. And that means a shift toward cleaner energy, away from oil, gas, and coal, is urgent not only for heading off a frightening future of droughts, floods, wildfires, and storms. It also will make us healthier now—with the most affected communities likely to reap the biggest gains. Just switching to electric vehicles could save thousands of lives and $72 billion in health damage annually in the U.S., according to the American Lung Association.

IN THE U.S., ELECTRIC VEHICLES COULD SAVE THOUSANDS OF LIVES AND $72 BILLION IN HEALTH COSTS EACH YEAR.

Victoria sees hope in that. He believes industries like electric truck manufacturing can bring his community new economic opportunities along with cleaner air. "We don't necessarily have to sacrifice our quality of health or our air quality for a job," he said. "We can have both."

CLIMATE CHANGE and air pollution have the same cause and the same solution, but they play out on different time scales. One of the most striking things about air pollution is how quickly health improves when it clears. The economic shutdowns triggered by COVID-19 last year temporarily slowed the world's carbon emissions, but the total amount of carbon in the atmosphere continued to rise, and the long-term threat from

climate change got that much worse. In contrast, every incremental and local decline in pollutants such as PM2.5 or nitrogen dioxide translates immediately into fewer asthma attacks, heart attacks, and deaths.

In China, researchers drew a stunning conclusion: Improved air quality during the lockdown in early 2020 saved upwards of 9,000 lives, according to one study, and roughly 24,000, according to another—more lives than the virus took, in any case, at least according to China's official statistics, which put the COVID-19 toll below 5,000. Scientists have long understood that better air saves lives, said Yale epidemiologist Kai Chen, lead author of the first study. But "it's just so dramatic" to see it happen.

IN CHINA, IMPROVED AIR QUALITY IN EARLY 2020 MAY HAVE SAVED MORE LIVES THAN THE VIRUS TOOK.

While the pandemic's deadly impact has been impossible to ignore, pollution gets far less attention, though it kills far more people. One reason, Dominici suggested, is that it's so hard to link pollution to individual deaths—to attach names and faces to the victims. One person who has managed to change that is Rosamund Adoo Kissi-Debrah, Britain's best known clean-air activist. Living in London, I've gotten to know her a bit. We met again on a sunny day last summer for a socially distanced chat, in a park bursting with wildflowers.

Kissi-Debrah's eldest daughter, Ella, died from asthma at age nine in 2013. The family lives less than a hundred feet from one of London's busiest roads, the South Circular, and Kissi-Debrah now believes its exhaust fumes were what sickened Ella. She's spent years waging a legal battle to prove it. A teacher before grief upended her life, she has turned tragedy into a teachable moment by getting pollution officially added to Ella's death certificate as a contributing factor.

After Ella's death, Stephen Holgate, a University of Southampton asthma specialist, found that many of the child's dozens of hospitalizations, including the final one, had coincided with pollution spikes. With cleaner air, he concluded, Ella might well be alive. As a parent, "that's quite hard to take," Kissi-Debrah told me. Three silver hearts hung from a chain around her neck, engraved with the fingerprints of Ella and two younger children.

Ella was active and energetic before she got sick, and even between bouts of asthma, Kissi-Debrah recalled. "Everything came easily to her"—reading, music, swimming. Ella's attacks were so bad they sometimes triggered seizures. But as soon as she felt better, "she wanted to get on her skateboard. She was a real tomboy."

At the first inquest in 2014, the coroner decided Ella had died of acute respiratory failure and asthma, without considering any external cause. Kissi-Debrah pressed on, and her fight drew wide media coverage. Getting pollution written onto Ella's death certificate, she believed—a British and perhaps a world first—might be cold comfort for her, but it would have moral and political power. A legal judgment that Britain's air helped end the life of one child would unmistakably imply that it endangers others—and that something should be done.

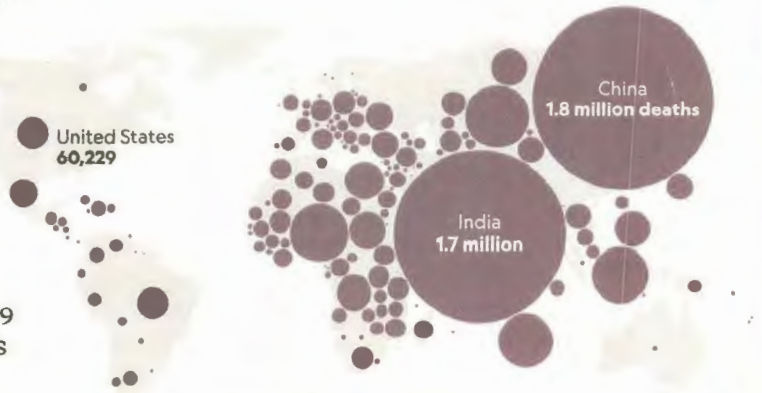
Kissi-Debrah knows the answers aren't complicated. Tough, science-based regulations work, if governments enforce them. "My daughter wasn't the only one," she said. For the rest of London's kids, "I want real change." I thought of my own daughter, growing up in the fumes.

Last December, with the second inquest finally under way, Holgate compared Ella to "a canary in a coal mine." He testified that she had been through more than two years of regular "near-death experiences" before succumbing. In the end, the coroner ruled that air pollution—which was beyond British legal limits near Ella's home—had indeed contributed to her death. For once, the seven million lives lost each year to dirty air were represented by a face. It belonged to a beautiful young girl. ◻

Beth Gardiner is the author of *Choked: Life and Breath in the Age of Air Pollution*. Photographer **Matthieu Paley** has shot multiple stories for the magazine in India and Central Asia.

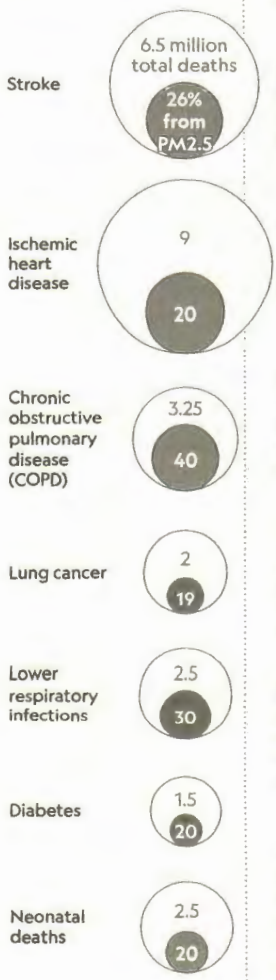
POLLUTION'S TOLL ON THE BODY

Dirty air is a complex mix of gases and particles. PM2.5 particles, some of which are so small they pass into the bloodstream, are the deadliest. In 2019 air pollution, indoors and out, is estimated to have contributed to almost seven million deaths worldwide, accounting for nearly 12 percent of the global death toll.



Number of deaths from air pollution
2019, by country

Global percentage of deaths from PM2.5
2019, by ailment



Brain
Long-term exposure to particulate matter, sulfur dioxide, and nitrogen dioxide can lead to cognitive declines. Changes in brain structure increase the risk of Alzheimer's disease.

Nervous system
Pollution is linked to neurodevelopmental disorders and deaths from Parkinson's. Particles can travel to the central nervous system and activate immune responses.

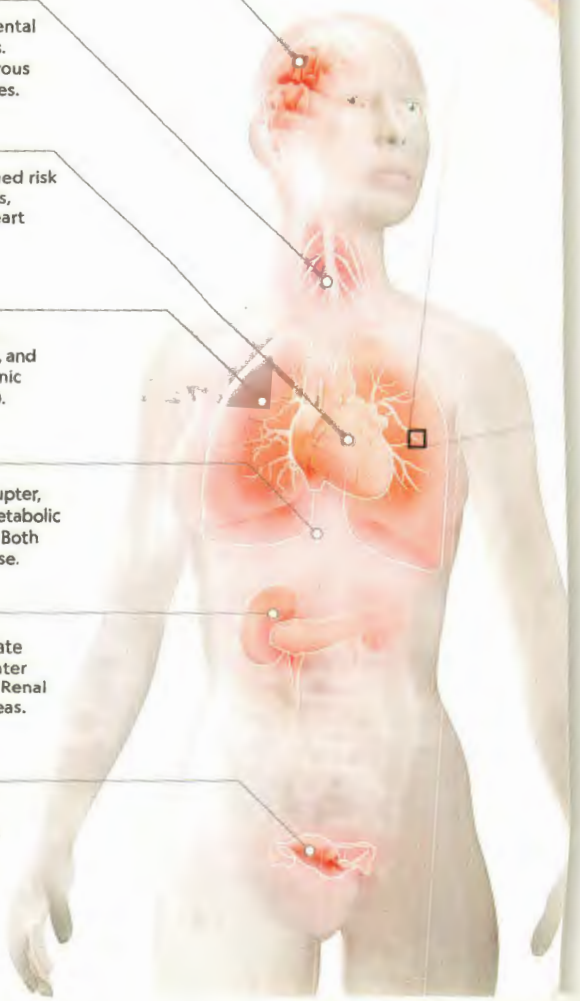
Cardiovascular system
Exposure is associated with heightened risk of death from cardiovascular diseases, including coronary artery disease, heart attacks, strokes, and blood clots.

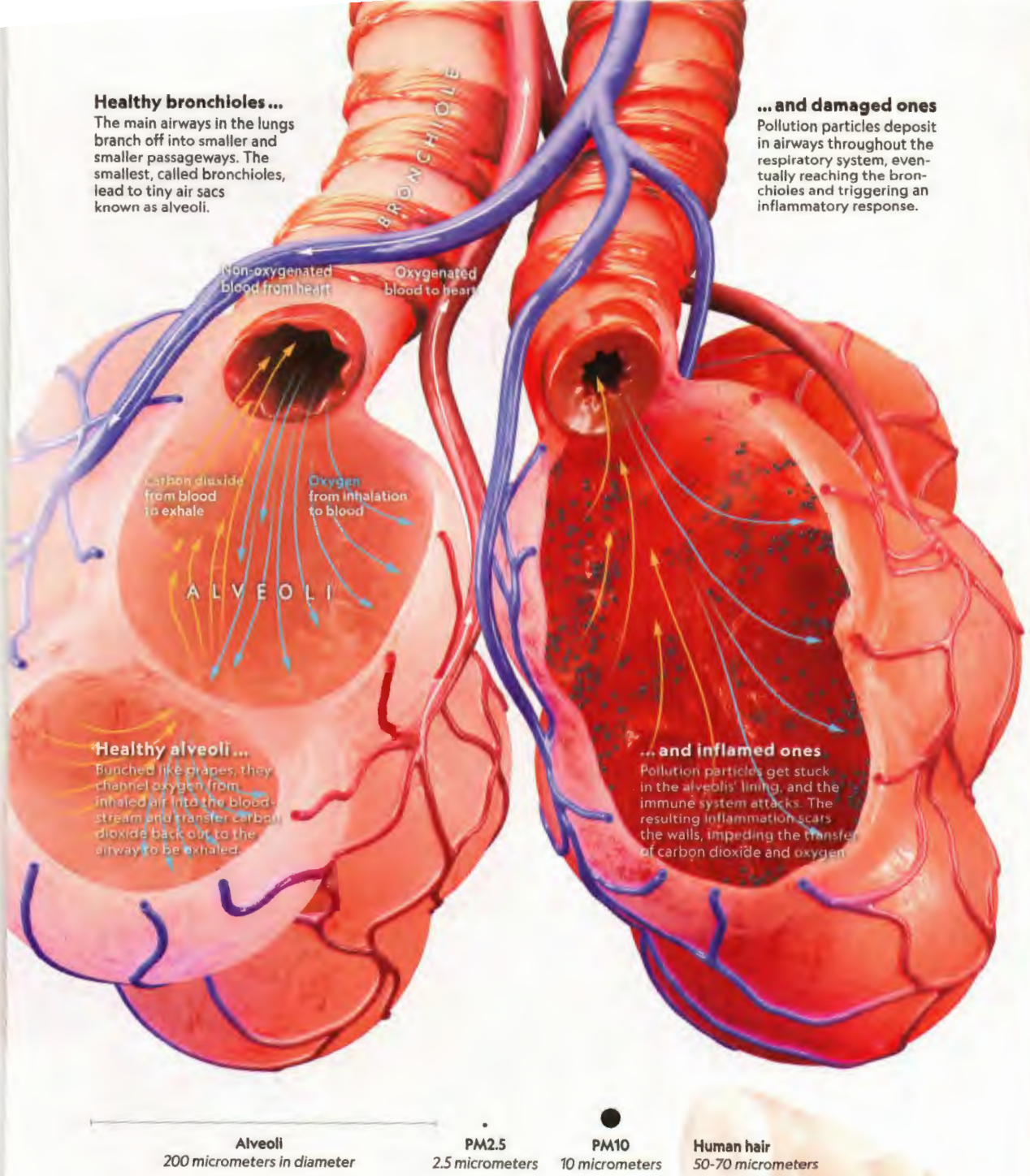
Respiratory system
Pollution can irritate airways and cause shortness of breath, coughing, asthma, and lung cancer. It can raise the risk of chronic obstructive pulmonary disease (COPD).

Endocrine system
Particulate matter is an endocrine disrupter, contributing to the development of metabolic diseases such as obesity and diabetes. Both are risk factors for cardiovascular disease.

Renal system
Long-term exposure to fine-particulate air pollution is associated with a greater likelihood of chronic kidney disease. Renal disease rates are highest in urban areas.

Reproductive system
Pollution is linked to diminished fertility and unsuccessful pregnancies. Prenatal exposure can lead to premature births, low birth weight, and respiratory diseases.




Healthy bronchioles ...
The main airways in the lungs branch off into smaller and smaller passageways. The smallest, called bronchioles, lead to tiny air sacs known as alveoli.
... and damaged ones
Pollution particles deposit in airways throughout the respiratory system, eventually reaching the bronchioles and triggering an inflammatory response.
BRONCHIOLE
Non-oxygenated blood from heart
Oxygenated blood to heart
Carbon dioxide from blood to exhale
Oxygen from inhalation to blood
ALVEOLI
Healthy alveoli ...
Bunched like grapes, they channel oxygen from inhaled air into the bloodstream and transfer carbon dioxide back out to the airway to be exhaled.
... and inflamed ones
Pollution particles get stuck in the alveolis' lining, and the immune system attacks. The resulting inflammation scars the walls, impeding the transfer of carbon dioxide and oxygen.
Alveoli
200 micrometers in diameter
PM2.5
2.5 micrometers
PM10
10 micrometers
Human hair
50-70 micrometers

LEADING POLLUTANTS

PM2.5
Factories, vehicle exhaust, waste and wood burning, and wildfires are common sources. These fine particles can travel to the alveoli and reach the bloodstream.

PM10
Sources include road dust, wildfires, and vehicle exhaust. Particles can get trapped in the nose and upper airway; our bodies clear them by sneezing or coughing.

Nitrogen dioxide
NO_2 primarily comes from the burning of fossil fuels by vehicles and power plants. It irritates the airways and can lead to the development of asthma.

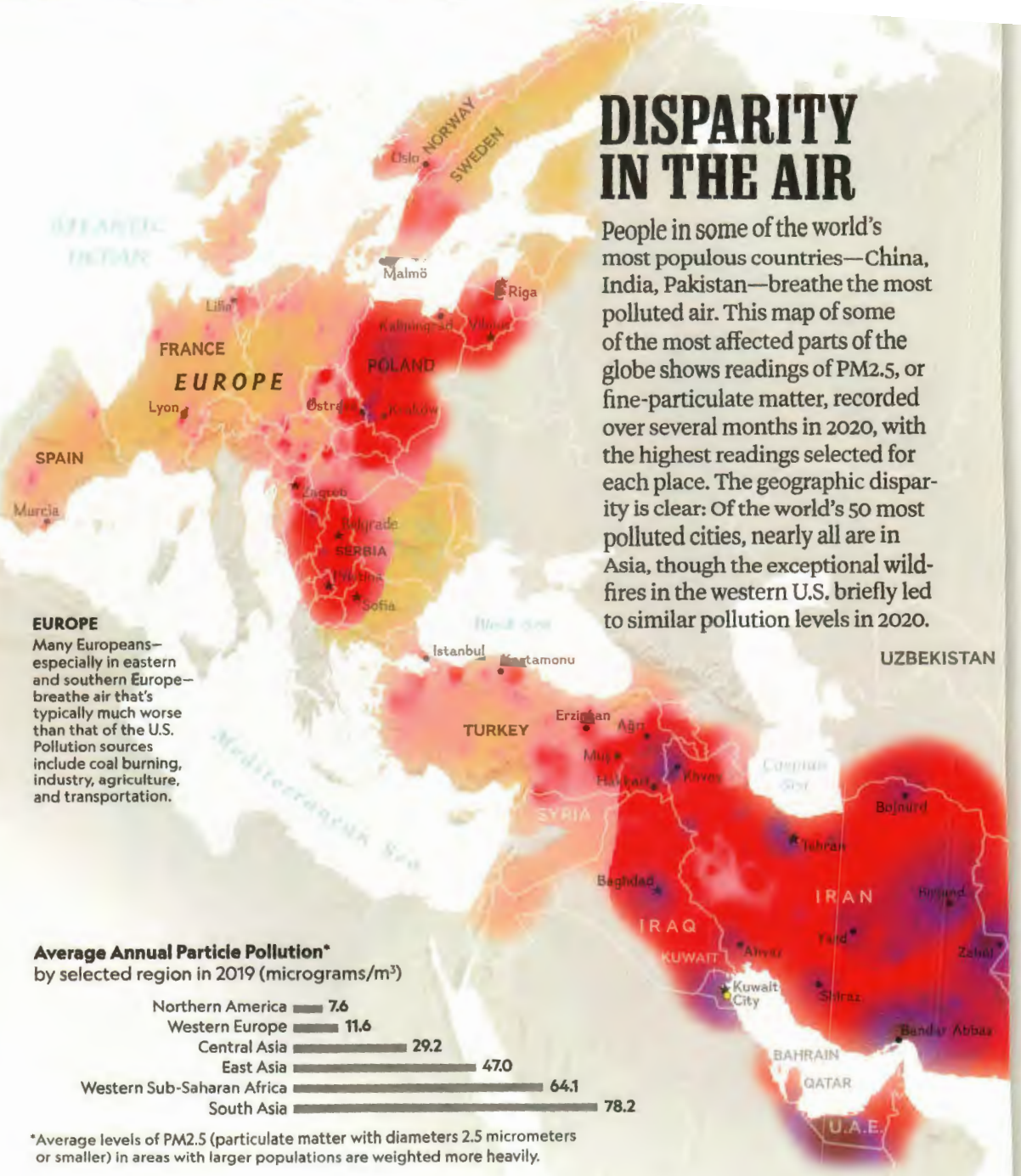
Ozone
Ground-level ozone is created when vehicle and industry emissions chemically react in sunlight. Inhaling it can trigger chest pain, coughing, throat irritation, and inflammation.

Sulfur dioxide
The burning of fossil fuels by power plants and other industrial facilities is the largest source of SO_2; natural sources include volcanoes. Exposure makes it hard to breathe.

JASON TREAT AND RYAN MORRIS, NGM STAFF; KELSEY NOWAKOWSKI. ART: MAGIC TORCH.
SOURCES: MEREDITH MCCORMACK, AMERICAN LUNG ASSOCIATION AND JOHNS HOPKINS UNIVERSITY; STATE OF GLOBAL AIR; GLOBAL BURDEN OF DISEASE

DISPARITY IN THE AIR

People in some of the world's most populous countries—China, India, Pakistan—breathe the most polluted air. This map of some of the most affected parts of the globe shows readings of PM2.5, or fine-particulate matter, recorded over several months in 2020, with the highest readings selected for each place. The geographic disparity is clear: Of the world's 50 most polluted cities, nearly all are in Asia, though the exceptional wildfires in the western U.S. briefly led to similar pollution levels in 2020.



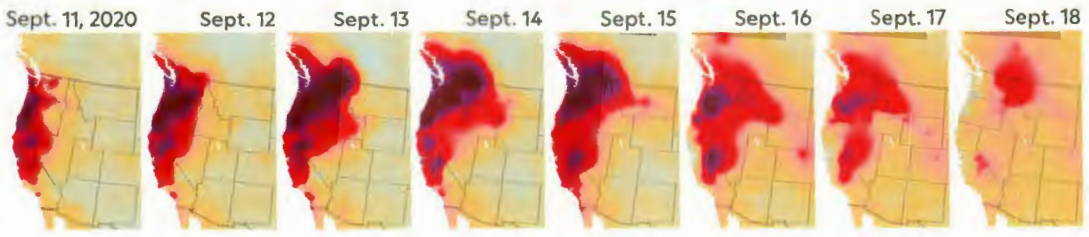
EUROPE
Many Europeans—especially in eastern and southern Europe—breathe air that's typically much worse than that of the U.S. Pollution sources include coal burning, industry, agriculture, and transportation.

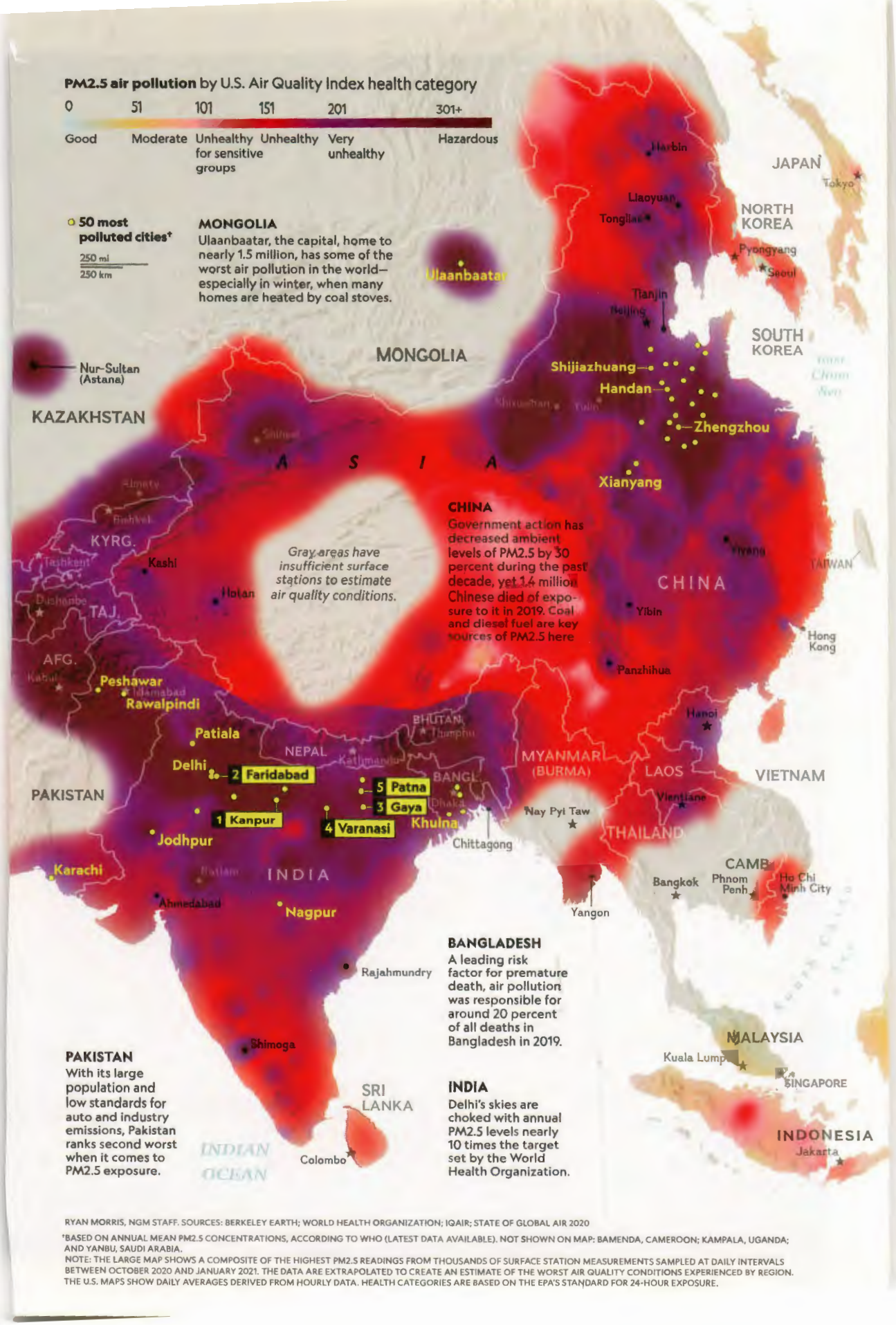
Average Annual Particle Pollution*
by selected region in 2019 (micrograms/m³)

*Average levels of PM2.5 (particulate matter with diameters 2.5 micrometers or smaller) in areas with larger populations are weighted more heavily.

WHEN THE U.S. RANKED AMONG THE WORST

In September 2020 the West Coast had some of the worst air pollution in the world because of raging wildfires. It saw levels of PM2.5 typically associated with large cities in Asia, such as Delhi, India.





RYAN MORRIS, NGM STAFF. SOURCES: BERKELEY EARTH; WORLD HEALTH ORGANIZATION; IQAIR; STATE OF GLOBAL AIR 2020

*BASED ON ANNUAL MEAN PM2.5 CONCENTRATIONS, ACCORDING TO WHO (LATEST DATA AVAILABLE). NOT SHOWN ON MAP: BAMENDA, CAMEROON; KAMPALA, UGANDA; AND YANBU, SAUDI ARABIA.

NOTE: THE LARGE MAP SHOWS A COMPOSITE OF THE HIGHEST PM2.5 READINGS FROM THOUSANDS OF SURFACE STATION MEASUREMENTS SAMPLED AT DAILY INTERVALS BETWEEN OCTOBER 2020 AND JANUARY 2021. THE DATA ARE EXTRAPOLATED TO CREATE AN ESTIMATE OF THE WORST AIR QUALITY CONDITIONS EXPERIENCED BY REGION. THE U.S. MAPS SHOW DAILY AVERAGES DERIVED FROM HOURLY DATA. HEALTH CATEGORIES ARE BASED ON THE EPA'S STANDARD FOR 24-HOUR EXPOSURE.

AS POLLUTION FROM CATASTROPHIC WILDFIRES GROWS, SCIENTISTS ARE INVESTIGATING WHAT'S IN THAT SMOKE— AND WHAT IT'S DOING TO OUR HEALTH.

WHERE THERE'S FIRE, THERE'S TOXIC SMOKE

BY **CYNTHIA GORNEY**
PHOTOGRAPHS BY **STUART PALLEY**

As the Glass Fire ripped through California's Napa and Sonoma Counties last September, firefighters battled its advance by lighting a contained blaze to deprive the wildfire of fuel. This common strategy produces its own smoke—and wildland firefighters don't use filtering respirators. No respirators have been designed that are effective and lightweight enough to work for these men and women, whose shifts can last for many hours without breaks and demand long hikes with heavy equipment in steep terrain. The firefighters are exceptionally fit, but researchers worry about the toll on their health as wildfires increase in size and duration. Recent studies to gauge the impact have tracked firefighters' blood samples and provided them with pocket-size pollution monitors to carry into the smoke.

PREVIOUS PHOTO

The Angeles National Forest, in Southern California, is engulfed in smoke and flames during last year's record-breaking wildfire season. The Bobcat Fire, as this one was called, burned more than 115,000 acres. It was one of scores that blew smoke pollution across the western states and beyond—visible as far away as Washington, D.C.

ON A RURAL HIGHWAY in Northern California, a July traveler's tire went flat. Metal rim scraped against pavement. The sparks ignited a fire that ripped through dry forest, whirled into flame tornadoes, and roared over tens of thousands of acres, making fuel of everything in its path. When it jumped the Sacramento River and headed for the city of Redding, Keith Bein prepped his new rig—a trailer holding two tiny electric cars, a lot of tubes and instrumentation, and a white contraption that looks like a miniature lighthouse.

Bein works as an atmospheric scientist at the University of California, Davis campus, about 150 miles south of Redding. By the time he hooked the loaded trailer to his truck and began driving upstate, the 2018 Carr Fire—those sparks ignited near a power plant called Carr—was already one of the biggest wildfires in California history. It had killed six people, including two firefighters. It was burning trees, grasslands, mountain cabins, pedestrian bridges, light posts, fences, parked cars. At the Redding outskirts it had just burned a suburb called Lake Keswick Estates, which meant the full infrastructure of single-family housing: insulation, shingles, refrigerators, paint.

And everywhere around the Carr Fire's great trajectory was smoke—billowing, blanketing, spreading thousands of miles beyond the actual flames. Of all the things that foul the air we breathe, it's wildfire smoke that most fascinates Bein.

He wants to understand exactly what's in it, how its chemistry differs from one fire to the next, and what this century's unprecedented megafires mean for global air pollution and human health. In western North America and in Australia, as measured by the size and number of wildland fires, 2018 was the worst year in recorded history—until 2020 eclipsed it.

"An event like this used to happen, like, once in your lifetime—where your personal life was impacted by a huge wildfire," Bein says. "Now it's happening every summer. That's a major public health concern."

So there he was at Lake Keswick Estates, the ground charred, the residents evacuated, whole blocks of houses leveled to their smoldering foundations. He braced the trailer and powered up the contraption, which is actually a sophisticated air pump and sensor. He pulled tubing and monitors from the electric cars, which provide mobile rechargeable power for the whole setup. His eyes and nose hurt. Imagine yourself by a campfire, Bein says, when the wind shifts and shoves smoke directly into your face. "Absolutely horrible," he says.

But perfect for his work. Although the flames had moved on, Bein and other researchers know smoldering produces its own intensely toxic smoke. They know the construction of so many residences amid and alongside wildland areas has created communities that are affordable and scenic—and vulnerable, as the warming climate parches forests into tinder. Wildland-urban interface, they call such places, or WUI (which in wildfire parlance is pronounced like a cry of astonishment, *woo-eee*). They know giant WUI fires make giant WUI smoke: burning-landscape plus burning-building pollution, roiling together into one noxious mix.

WHAT'S ACTUALLY in that mix? And what happens to humans and other animals breathing emissions from such huge conflagrations? These questions are an increasingly urgent part of the effort to understand and reduce air pollution, and the answers are more elusive than you might imagine. Think about what it takes to bring real wildfire smoke into a research facility. You need to become the equivalent of a tornado chaser, explaining your way through police barricades, as Bein does when the situation calls for it. Or you rig up a C-130 cargo plane with smoke-sucking fuselage tubes and fly straight into wildfire plumes, like the research team that spent the summer of 2018 making sorties over fires in Colorado and Idaho.

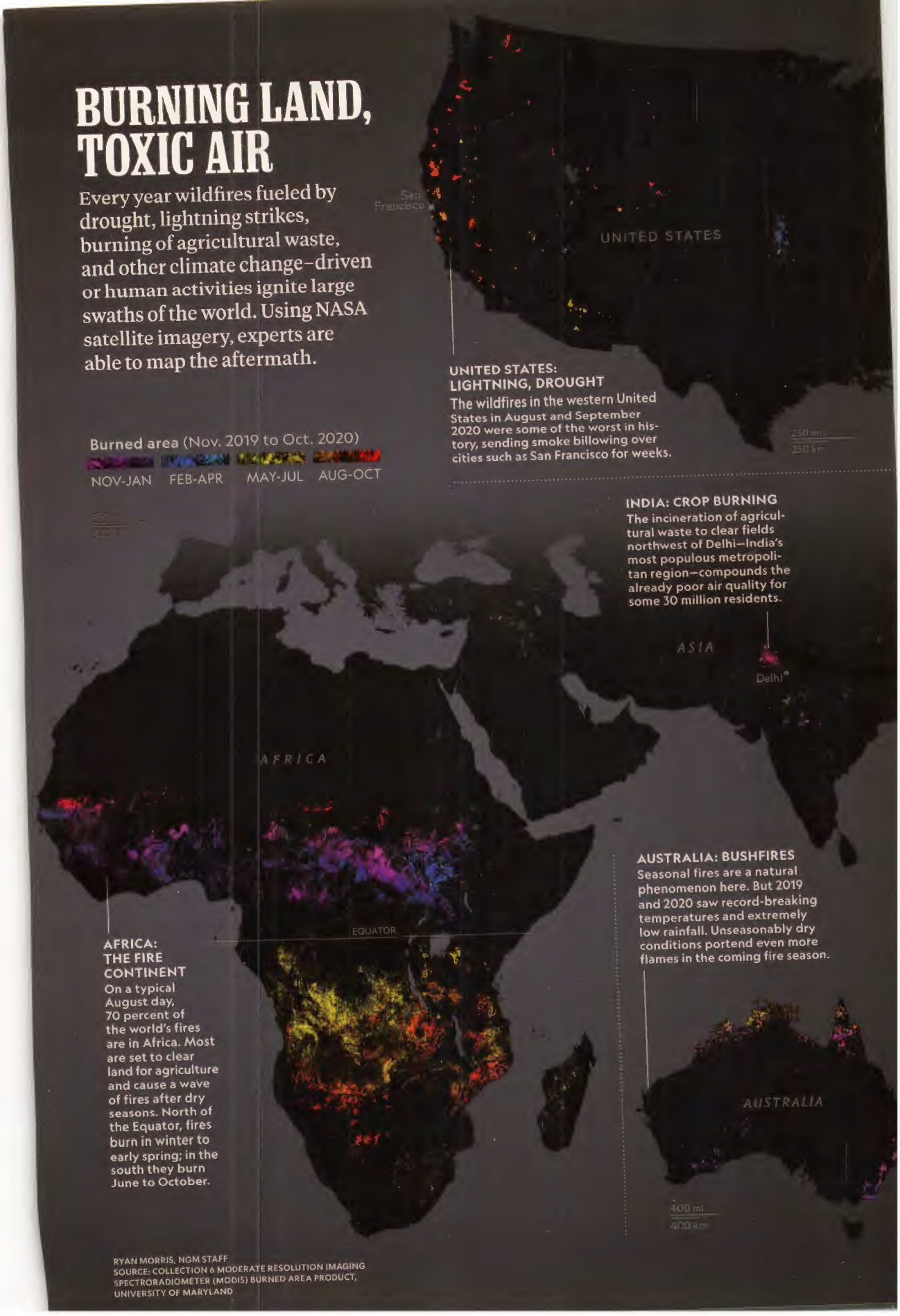
"We turn the airplane into a flying chemistry lab," says Colorado State University atmospheric scientist Emily Fischer, who leads the researchers analyzing what they found in the smoke. The ingredients include carbon monoxide, hydrogen cyanide, and more than a hundred other gases, as well as the dangerous fine particles (PM2.5) Beth Gardiner describes in her story (see page 40). There's no dispute about the most immediate health hazard: Wildfires pollute, whether the smoke is WUI or "natural," and just a few days of enough exposure to their smoke can send people with asthma or other sensitivities to emergency rooms.

It's also possible—the evidence is "inconclusive," as scientists say—that breathing a wildfire's smoke kicks off the kind of cellular changes that could lead to later health calamities: heart failure, lung disease, stroke. Questions have arisen about Alzheimer's disease too. Just figuring out how best to explore these links has been an extraordinary challenge for researchers; you can't start a true wildfire for experimental purposes. They have to take into account the physical and emotional stress any wildfire can set off, even for people not in the path of the flames. And the smoke itself keeps changing during a fire, no matter what's being burned, as its components heat and cool and interact. "The chemistry of each burn can result in different health outcomes," says Lisa Miller, a respiratory immunologist at the California National Primate Research Center. "This is going to take us a while to sort out."

About 4,000 monkeys live at the primate center, many in outdoor enclosures, and it was a smoke-bleak day during the state's bad 2008 wildfires that gave Miller the idea to start a multiyear study of the newest group of rhesus babies—who were spending their first weeks of life breathing wildfire smoke. Moving the newborns inside for protection wasn't an option, Miller says; that would have disrupted social groupings, as there's not enough indoor

BURNING LAND, TOXIC AIR

Every year wildfires fueled by drought, lightning strikes, burning of agricultural waste, and other climate change–driven or human activities ignite large swaths of the world. Using NASA satellite imagery, experts are able to map the aftermath.



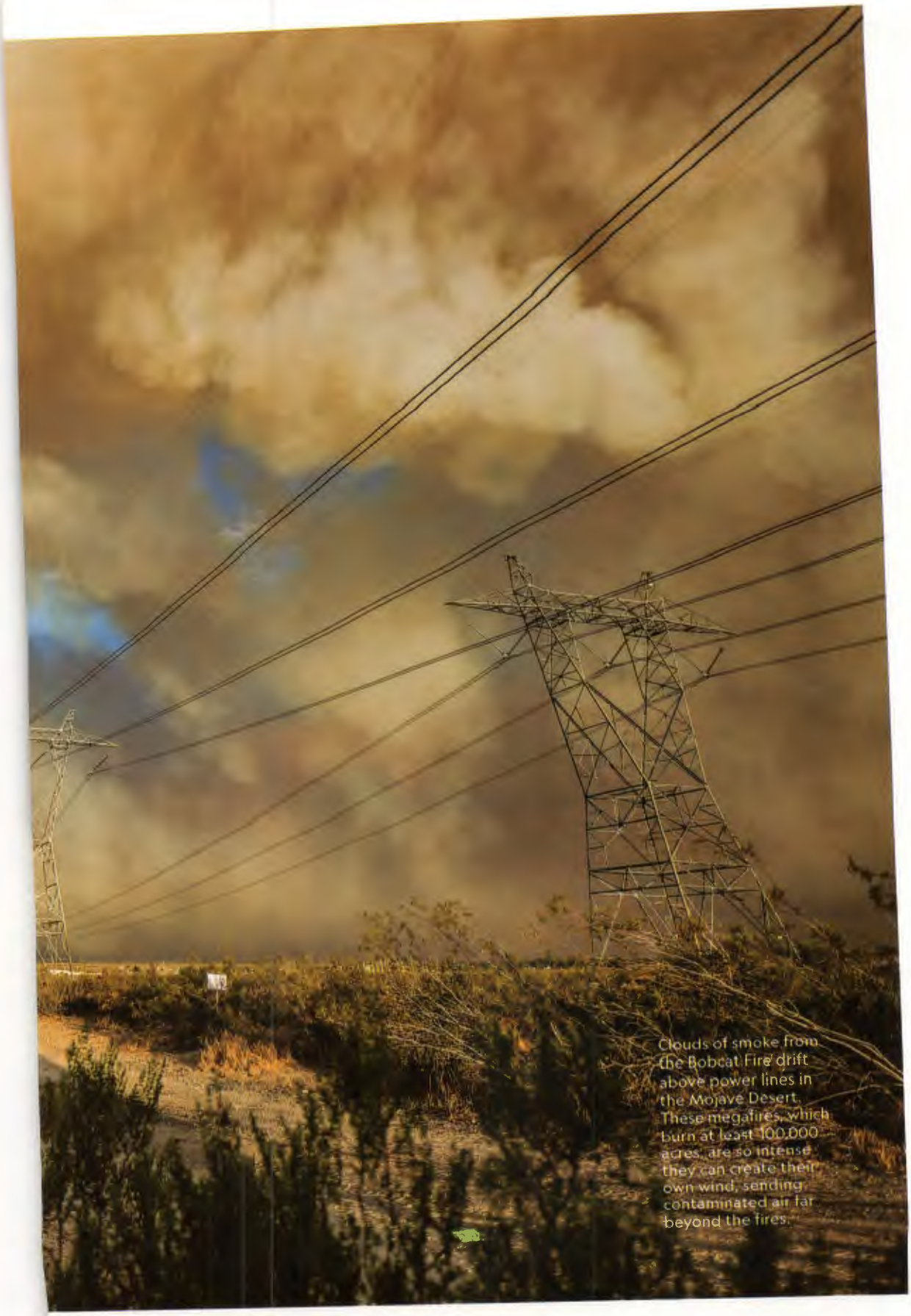
UNITED STATES: LIGHTNING, DROUGHT
The wildfires in the western United States in August and September 2020 were some of the worst in history, sending smoke billowing over cities such as San Francisco for weeks.

INDIA: CROP BURNING
The incineration of agricultural waste to clear fields northwest of Delhi—India's most populous metropolitan region—compounds the already poor air quality for some 30 million residents.

AFRICA: THE FIRE CONTINENT
On a typical August day, 70 percent of the world's fires are in Africa. Most are set to clear land for agriculture and cause a wave of fires after dry seasons. North of the Equator, fires burn in winter to early spring; in the south they burn June to October.

AUSTRALIA: BUSHFIRES
Seasonal fires are a natural phenomenon here. But 2019 and 2020 saw record-breaking temperatures and extremely low rainfall. Unseasonably dry conditions portend even more flames in the coming fire season.

RYAN MORRIS, NGM STAFF
SOURCE: COLLECTION 6 MODERATE RESOLUTION IMAGING SPECTRORADIOMETER (MODIS) BURNED AREA PRODUCT, UNIVERSITY OF MARYLAND



Clouds of smoke from the Bobcat Fire drift above power lines in the Mojave Desert. These megafires, which burn at least 100,000 acres, are so intense they can create their own wind, sending contaminated air far beyond the fires.

housing for all the animals. Her team and the center's veterinarians have kept close watch on the group exposed as infants, and now at 12 years old—the rhesus equivalent of human millennials—the monkeys aren't showing health problems serious enough to warrant treatment. But there are troubling signs. When their blood samples are exposed to infection in the lab, the immune responses are sluggish. And compared to rhesus babies born in 2009, a year with cleaner air, the monkeys who breathed heavy smoke during their first weeks of life have smaller lungs and airways that appear impaired. The parallels for humans are worrisome. "Usually you're not diagnosed with chronic obstructive pulmonary disease or fibrosis until you're in your late 50s or early 60s," Miller says. "So we think what we're seeing is perhaps the early stages of a chronic lung condition."

It bears remembering that most of the world's air pollution still comes from other sources: tailpipes, furnaces, industrial plants, foliage-clearing agricultural burns, indoor cooking fires. But wildfires are multiplying and enlarging so rapidly that we have new vocabulary for them. *Megafire* lacks formal definition, but it's generally used to mean at least 100,000 acres of burning terrain. A few years ago, when the online journal *Wildfire Today* asked its audience to suggest names for even bigger conflagrations, a reader came up with one at once. You may have seen it in headlines last summer: *Gigafire.*

Fires as distant as Oregon made San Francisco's sky look like a dystopian movie set one day in September. Regional authorities called a Spare the Air Day alert: air quality hazardous enough to require special precautions. In 2020 the number of times they made that call because of wildfires more than doubled the previous record.

GABRIELLE LURIE, *SAN FRANCISCO CHRONICLE* VIA GETTY IMAGES

MEGAFIRES WRECK far more than the air we breathe, of course, and the proposals for what to do about them are by turns daunting, expensive, and counterintuitive. Daunting: Stop global warming, which is heating wildlands, drying foliage, killing trees, and producing weird weather like the 14,000 lightning strikes in 2020 that started California's August Complex gigafire—more than a million acres. "We're using terms like 'mega' and 'giga,' but it's really just the beginning," says University of Tasmania epidemiologist Fay Johnston, one of the world's leading wildfire smoke researchers. "If we don't do anything about climate change, we ain't seen nothing yet."

Expensive: Thin wildlands aggressively, hauling away dead trees and other dried-out debris that built up because we've spent so many years reflexively putting out wildfires. This is a huge task. It would cost a great deal for machinery and labor.

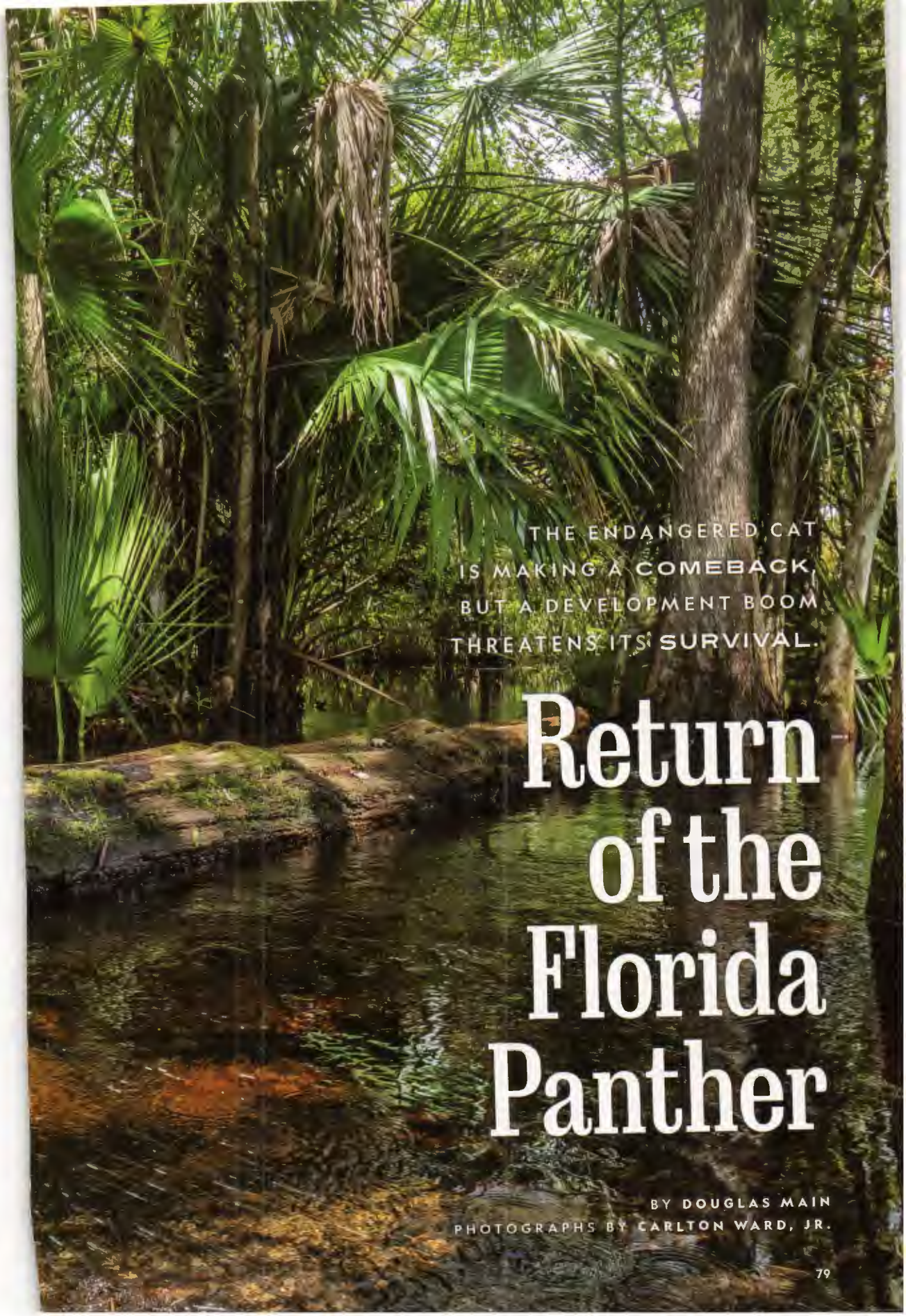
Counterintuitive: Use fire. Let more small wildfires burn when they aren't endangering homes; that's nature's way of clearing the debris and encouraging new growth. Indigenous people understood prudently contained flames as a land management tool, and nearly every megafires proposal includes a plea for more prescribed fires—planned, that is, with careful consideration of wind and the impact on people living nearby. Yes, these smaller fires make smoke too. But not as much. Says Donald Schweizer, a University of California, Merced air quality researcher: "There really is no 'no smoke' option."

Even in regions where clean air regulations have lowered other forms of air pollution, air purifiers and personal air quality monitors, like the new apps that let you check smoke contamination levels wherever you happen to be, are a grim growth industry. Bein brought his first purifier into his family's Oakland home during 2017's terrible fires; now they own six. "It's not a matter of *if*," he says. "It will happen again."

At his UC Davis lab, Bein says, nearly everything shut down early last year for the pandemic as he and his team were well into what he calls "the first layer" of pulling chemical and toxicological information from his Carr Fire smoke samples. He and his co-workers were determined to continue collecting, so even though the rig was grounded, they set up a sampling site on the roof of a university building. A graduate student kept climbing up to collect and replace the filters on the air pump, and by winter, when the historic 2020 fires finally stopped, Bein had a collection of more than six dozen sheets of scientific-grade filter paper, each loaded with evidence and wrapped in wax paper for protection. "I've already had a lot of requests for these samples," Bein says. He's storing them in a freezer, for now, at 80°C below zero. ▯

Contributing writer **Cynthia Gorney** lives in California and recently bought a home air purifier. **Stuart Palley** is a trained wildland firefighter and has documented more than a hundred California fires.

A male panther leaps over a creek at Florida Panther National Wildlife Refuge in southwestern Florida. The rarely seen cats, which number only around 200, are reclaiming territory north of the Everglades, but their habitat is threatened by encroaching suburban sprawl.

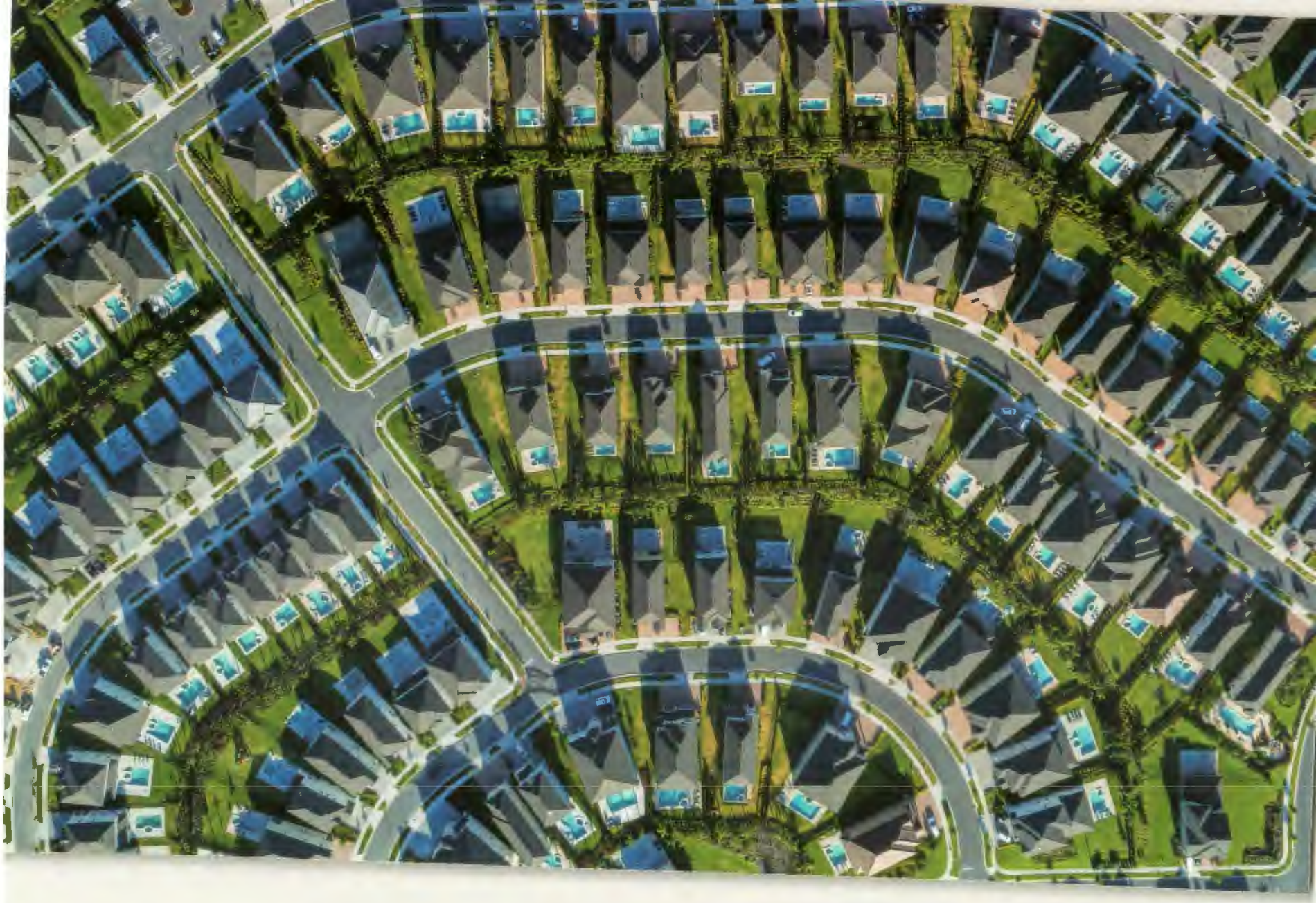


THE ENDANGERED CAT IS MAKING A COMEBACK, BUT A DEVELOPMENT BOOM THREATENS ITS SURVIVAL.

Return of the Florida Panther

BY DOUGLAS MAIN
PHOTOGRAPHS BY CARLTON WARD, JR.

Roads foster suburban development, such as this new neighborhood near Orlando, which cuts into historic panther habitat. One study projects that an additional five million acres—and most of the unprotected connections within Florida's wildlife corridor—will be developed by 2070 unless major investments in land conservation steer construction closer to existing urban areas.



'Welcome to panther country,'

Brian Kelly says when I meet him at a busy intersection in East Naples, Florida, a stone's throw from a gas station and an urgent care center.

Kelly, a state panther biologist, points east into the sprawling subdivision where he lives. A panther was caught on camera just a quarter mile away, he says, and another one made it across the six-lane road we're standing beside.

Yet another panther, an eight-year-old female named FP224, lives nearby. She's been hit by a car twice, breaking a leg each time. She was treated by veterinarians and released after both accidents. To look for signs of her, we drive to Kelly's house, next to a patch of forest where she recently denned and birthed at least three kittens. It's the wet season, when panther tracks typically are wiped out by rain, but we get lucky.

"There she is," Kelly says, pointing to large paw prints, about the size of my fist, in the soft sand. We follow the prints through tall pines and sabal palms festooned with air plants. A check of a motion-triggered camera trap Kelly placed there reveals that FP224 walked by just before 9 p.m., two evenings earlier.

Her tracks are thrilling to see—a reminder that Florida still has wilderness and large cats, some of them resilient enough to live unseen along the fringes of the expanding suburbs.

Most Floridians will never see any signs of these predators, which weigh from 65 to 165 pounds as adults, depending on sex, and can

The National Geographic Society, committed to illuminating and protecting the wonder of our world, has funded Explorer Carlton Ward, Jr.'s work in photographing and conserving the Florida panther since 2011.

ILLUSTRATION BY JOE MCKENDRY

A female and three kittens explore Corkscrew Swamp Sanctuary, a reserve of old-growth cypress forest surrounded by encroaching suburbs on three sides. Many of these camera trap images took years to capture because of the cats' rarity, their unpredictable movements, and the difficulty involved in getting the right lighting. Florida's weather can be a challenge too: One camera was lost during a hurricane but was later recovered.

leap more than 10 yards in a single bound. But the panther—known to the Cherokee as "lord of the forest"—depends on the millions of acres of swamps, forests, and fields in southwestern and central Florida, many of which are at imminent risk of development.

The Florida panther, classified as a subspecies of mountain lion, or cougar, once ranged throughout most of the southeastern United States. But the animals were hunted aggressively, and by the 1970s they were only found in Florida, and their numbers had fallen to fewer than 30, making them highly vulnerable to inbreeding. They were within a whisker of going extinct, says Kelly, a slim man often adorned in clothes bearing the insignia of his employer, the Florida Fish and Wildlife Conservation Commission.

Scientists back then hatched an unprecedented rescue plan: In the mid-1990s they hired Texan Roy McBride, arguably the world's best mountain lion tracker, to capture eight of the cats in Texas, all females, then release them into South Florida. Five of them bred, and this infusion of genetic diversity reversed the panther's downward spiral.

Populations grew slowly, and now there are about 200 individuals, most of them in a massive stretch of contiguous land south of the Caloosahatchee River, which stretches east from Fort Myers. "It's one of the most dramatic conservation success stories in U.S. history," says Carlton Ward, Jr., a conservationist and photographer whose work is supported by the National Geographic Society.

But a variety of threats cloud the panther's future, including car collisions and panther-on-panther territorial spats, the two leading causes of death. About 25 of the cats are killed by vehicles each year, a reflection of how development and road construction threaten the species at a time when roughly 900 people are moving to Florida every day.

Additionally, a new debilitating neurological condition with an unknown cause has afflicted more than a dozen panthers, alarming conservationists.

There is also good news, however: Panthers are reclaiming some of their old territory. In 2016 scientists spotted a female north of the Caloosahatchee River for the first time since 1973.

"That was a milestone," wildlife biologist Jennifer Korn says of the sighting in the Babcock Ranch Preserve. Unlike males, females don't travel far from their mother's home range, a major limiting factor in the animal's expansion.

About a couple dozen panthers now live north of the Caloosahatchee, Kelly estimates, including a few females.

The northward expansion is necessary for panthers to survive long term, but it's possible only if the Florida Wildlife Corridor, a patchwork of public and private lands that runs throughout the state, is preserved, Ward says. To make that possible, more conservation funding is needed to help landowners, mainly ranchers, prevent open spaces from becoming subdivisions, parking lots, and roads.

At the center of the panther's northward recovery is a landscape known as the Everglades headwaters, part of the watershed that supplies nearly 10 million Floridians. Some of the water that originates here reaches swamps to the south, and investments in protecting this area will help the Everglades as well, conservationists say.

ROOM TO ROAM

Florida's panther population is expanding, but struggling, in its human-dominated habitat. Because each cat may need up to 200 square miles of territory, the species must extend its range within the state and beyond to survive. As they push north, the cats face many dangers, from highways to hunters. To help panthers roam, conservationists have created a network of protected habitat on public and private lands throughout the state's interior, called the Florida Wildlife Corridor. Ranchers own much of this private land and generally support panther conservation.

Florida Wildlife Corridor

Protected areas

Unprotected habitat

Ranchlands

25 mi
25 km

Built-up area

Primary panther range (2017)

Documented panther observations outside range (1972–2020)

Panther killed by vehicle (1972–2020)

50 years from now...

If current growth trends continue, including a proposed 330-mile network of toll roads, Florida could become too highly developed for panthers. The cats would be confined to an area in the south too small to ensure their survival.

SOREN WALLJASPER, NGM STAFF
SOURCES: 1000 FRIENDS OF FLORIDA; FLORIDA FISH AND WILDLIFE; FLORIDA NATURAL AREAS INVENTORY; OPENSTREETMAP; USGS

Staff at the White Oak Conservation Center carry two sedated kittens whose mother, FP224, suffered a broken leg after being struck by a car. The mother was nursed back to health, and the family was returned to the wild. Shortly after their release, however, the kittens were killed when they were hit by cars in southwestern Florida.

A panther uses a newly added ledge to cross under State Road 80 near LaBelle, just south of Florida's Caloosahatchee River. Conservation easements have protected several ranches to the north and south in perpetuity. Panthers need to be able to cross below roads to move from protected lands in the south to new territory in the north. This photo was taken using infrared light, outside the visible spectrum, to avoid disturbing the cats.

MANY OF THE CATS in Florida live on public lands, including Big Cypress National Preserve, Florida Panther National Wildlife Refuge, Fakahatchee Strand Preserve State Park, and Picayune Strand State Forest, which make up about 1,420 square miles.

But these and nearby protected areas in South Florida cannot support a much larger population of these territorial animals, says state panther biologist Dave Onorato. Panthers may each need up to 200 square miles of territory in which to roam and hunt, he says. At the same time, populations of white-tailed deer, one of panthers' primary food sources, have dropped in areas of Big Cypress. That may be partly because of invasive Burmese pythons, which devour deer and other panther prey.

As panthers strike out north of the Caloosahatchee River, they'll encounter land dominated by large ranches and farms. Roads cut through many of these areas, and the region is dotted with small, often expanding towns. One of the better-known cattle operations in south-central Florida is the 10,500-acre Buck Island Ranch, run by Gene Lollis, a sixth-generation Floridian.

On a March morning before sunrise, I head out on horseback with Lollis, who's wearing a cowboy hat, boots, and blue jeans, along with his son, Laurent, and a group of cowboys, to round up cattle in grasslands spotted with islands of cabbage palm and oak.

Like many ranches, Buck Island—owned by the Archbold Biological Station, a nearby ecological research and education facility—provides critical habitat for wildlife, including panthers.

As dogs bay and cattle are rounded up, I ask Lollis, who leads the Florida Cattlemen's Association, how ranchers view the panther. "We're all pretty positive about them," he says. "They're part of the landscape."

Generally speaking, the rancher and the panther face a common enemy: development, particularly new housing. Every ranch owner has had an offer from developers, Lollis says, adding that the issue is deeply personal—ranches near Orlando where he worked as a young man have become subdivisions.

Some see the panthers' presence as a positive because it makes developing certain areas of land into suburbs more difficult.

"On the Endangered Species Act, do you see 'cowboy' or 'rancher' written on it? No, but we benefit from the protections afforded the panther," says Elton Langford, a rancher who lives to the west, near Arcadia.

But some ranchers, especially to the south, where there are more panthers, are warier, says Alex Johns, a Seminole cattleman whose family has ranched since his ancestors poached cows from the Spanish in the 1500s.

In this region, panthers occasionally eat calves. A study conducted at one ranch found panthers kill less than one percent of calves; another study found the predators killed around 5 percent.

Panthers sometimes are blamed for kills by coyotes, bears, and even buzzards, says Deborah Jansen, a Big Cypress National Preserve panther biologist who's worked with the felines since the early 1980s.

Calf loss can stir resentment and even lead to retaliation, cattleman Johns says. Making matters worse, the federal program that compensates ranchers for livestock losses because of panthers is flawed, he adds, describing a process in which the paperwork is difficult and

LEFT

Laurent Lollis and other cowboys round up cattle at Buck Island Ranch in south-central Florida. Such ranches take up nearly one-sixth of Florida's landmass but are imperiled by development. The survival of the panther and the success of the Florida Wildlife Corridor depend on the preservation of these agricultural lands.

BELOW

A panther creeps through a fence at Corkscrew Swamp Sanctuary, emerging from nearby ranchland. The sanctuary is too small to support even one adult male panther, which may require up to 200 square miles of territory for roaming and hunting. While a male's territory can overlap a little with that of another male, the solitary cats generally avoid each other.

time-consuming, and reimbursement often is not granted.

David Shindle, panther coordinator with the U.S. Fish and Wildlife Service, agrees that the reimbursement program needs improvement, and he sees the two sides as allies. "To save the panther, we have to save the rancher," he says.

Panther advocates, Shindle adds, need to find a way to incentivize the presence of the animals on the land—which is mostly private north of the Caloosahatchee River. One way to do that is to encourage public and private investment in conservation easements, which buy up development rights while allowing the owners to continue farming and ranching.

A MORE IMMEDIATE danger to panthers, conservationists say, is a proposed major network of toll roads known as M-CORES. Part of it would cut a 140-mile path from near Orlando to Naples.

Staunchly opposed by conservationists and many ranchers, this section of the road would slice through areas of the wildlife corridor and some of the last undeveloped parts of interior southwestern Florida.

On top of this, scientists have discovered a neurological condition called feline leukomyelopathy, which affects panthers and bobcats in Florida. Affected animals often stumble or have trouble walking, and severe cases can lead to paralysis, starvation, and death.

As of December 2020, 26 bobcats and 18 panthers are thought to have had the disease, according to state biologists. Three panthers have likely died from it in Big Cypress alone, Jansen says. The syndrome's cause is unknown, but theories include exposure to toxic chemicals or a pathogen such as a virus.

Most animals with the disease have been found in areas bordering developed land; seeing cases in more pristine areas, such as Big Cypress, is concerning, Jansen says.

Because of the threats panthers face, Jansen thinks "the future of the Florida panther is very much in question"—and is a major reason why expanding the cat's habitat is key.

Kelly is more optimistic. If enough green spaces and wildlife corridor areas are protected, he says, panthers could make it all the way to northern Florida within decades, and potentially spread to other states with rich panther habitat, including Georgia. In 2008 a male panther born near the Everglades made it to western Georgia, about a hundred miles north of the Florida state line, before being shot by a deer hunter.

Wildlife veterinarian Lara Cusack handles more kittens belonging to FP224. These young cats were measured and given immunity boosters while their mother was hunting away from the den. When panthers have space and protected habitats, their populations can grow. Only about one in three Florida panther kittens survives to adulthood.

In the meantime, Kelly and colleagues have placed around a hundred cameras at various spots north of the Caloosahatchee to learn more about how and where panthers move. A female recently lumbered through the Fisheating Creek area, as well as another in Babcock, and both were seen with males. That's cause for celebration, Kelly says, because coupled panthers often produce kittens.

ON A FALL AFTERNOON I walk with Kelly through muddy, dense brush to the edge of a creek in Babcock Ranch Preserve. Pointing to a tangle of sabal palms, he recalls seeing a panther here a month before.

"We just stared at each other for about 20 minutes," says Kelly, who quickly realized it was a female by her small size and because she was wailing, a sign of being in heat.

That was momentous—the first verified in-person sighting of a panther north of the Caloosahatchee River since the cougar tracker, Roy McBride, found an old female at Fisheating Creek in 1973.

This newfound female was "my white whale," Kelly says.

Later we take a swamp buggy through this area, 20 miles to the north, crossing flooded fields and meandering through thickets of palmetto and cypress hammocks. Wildlife here is plentiful: On a good day you can see bears, otters, alligators, and bird species including crested caracaras and swallow-tailed kites, all of which rely on the same wildlands as panthers.

Kelly stops to check a recently placed camera, looped around an oak tree. He flips through the photos, and sandwiched within all the usual suspects—coyotes, wild pigs, raccoons, deer—is a photo of a panther, which passed by a few weeks earlier.

And not just any panther: A lanky female, never before spotted by biologists, striding along the northern side of the fence separating the creek from the adjoining ranch—and perhaps to a new life up north. □

Staff writer **Douglas Main** wrote about treehoppers in the March 2019 issue. **Carlton Ward, Jr.,** has trekked more than 2,000 miles throughout Florida to bring attention to the state's wildlife corridor.

Iridescent orchid bees, tropical cousins of bumblebees and honeybees, were among the multitude of insects that entomologists collected at an observation tower in Brazil.

SILHOUETTES SHOW ACTUAL SIZE.

THE BUGS IN THE TREES

A novel experiment in the Amazon reveals hundreds of species of insects that live far above the rainforest's floor.

BY **HALEY COHEN GILLILAND**
PHOTOGRAPHS BY **CRAIG CUTLER**
AND **BRIAN BROWN**

Brian Brown, curator of entomology at the Natural History Museum of Los Angeles County, photographed all the insects in this article using a camera-and-microscope setup that was originally developed to examine flaws in computer chips.

1. This treehopper is one of more than 3,400 known species.

2. Some stingless bees defend their nests by dabbing caustic chemicals on invaders—including prying entomologists.

3. *Azteca* ant queens make onetime use of their wings to fly away, mate, and start a new colony.

4. This weevil's black-and-gray pattern mimics certain types of flies, perhaps to fool predators.

5. The mantis wasp uses its ovipositor—a needlelike organ for laying eggs—to pierce the egg cases of mantises. When the wasp's larvae hatch, they feed on the mantis's eggs.

6. Treehoppers are skilled at camouflage. The spots on this one help it blend in with the bark on trees.

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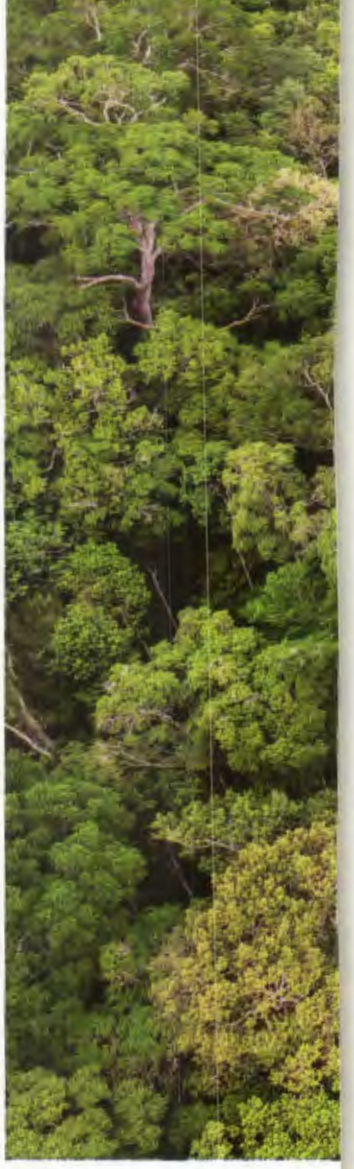
On a balmy January morning in Manaus, a Brazilian port city surrounded by rainforest, a group of entomologists and I scattered into a supermarket to stock up for an expedition.

Twenty minutes later, in the checkout line, it became clear that we had different ideas about what that meant.

I had peanuts, raisins, and bug repellent; the entomologists, all of whom were dipterists, or fly specialists, had heaps of bruised produce, nearly expired trays of chicken, and bits of peacock bass wrapped in cellophane.

"I asked for the worst tomatoes they have, the most rotten potatoes and onions—that's the kind of stuff flies like," said Dalton de Souza Amorim, a professor of entomology at the University of São Paulo.

Wearing a T-shirt stamped with a sketch of *Plagiocephalus latifrons*, a fly with a head shaped like bicycle handlebars, Amorim said dipterists



Entomologists often focus their attention on the ground. On this expedition, scientists instead studied insect life at different levels of a 131-foot research tower. They found a staggering diversity of insects, including hundreds of new species.

often use putrid food to bait traps on the ground, where the majority of their research is focused. But on this trip, he and his colleagues—Brian Brown, the entomology curator at the Natural History Museum of Los Angeles County; Stephen Marshall, an emeritus professor from the University of Guelph in Ontario; José Albertino Rafael of the National Institute of Amazonian Research (INPA); and two research assistants—had a more novel mission.

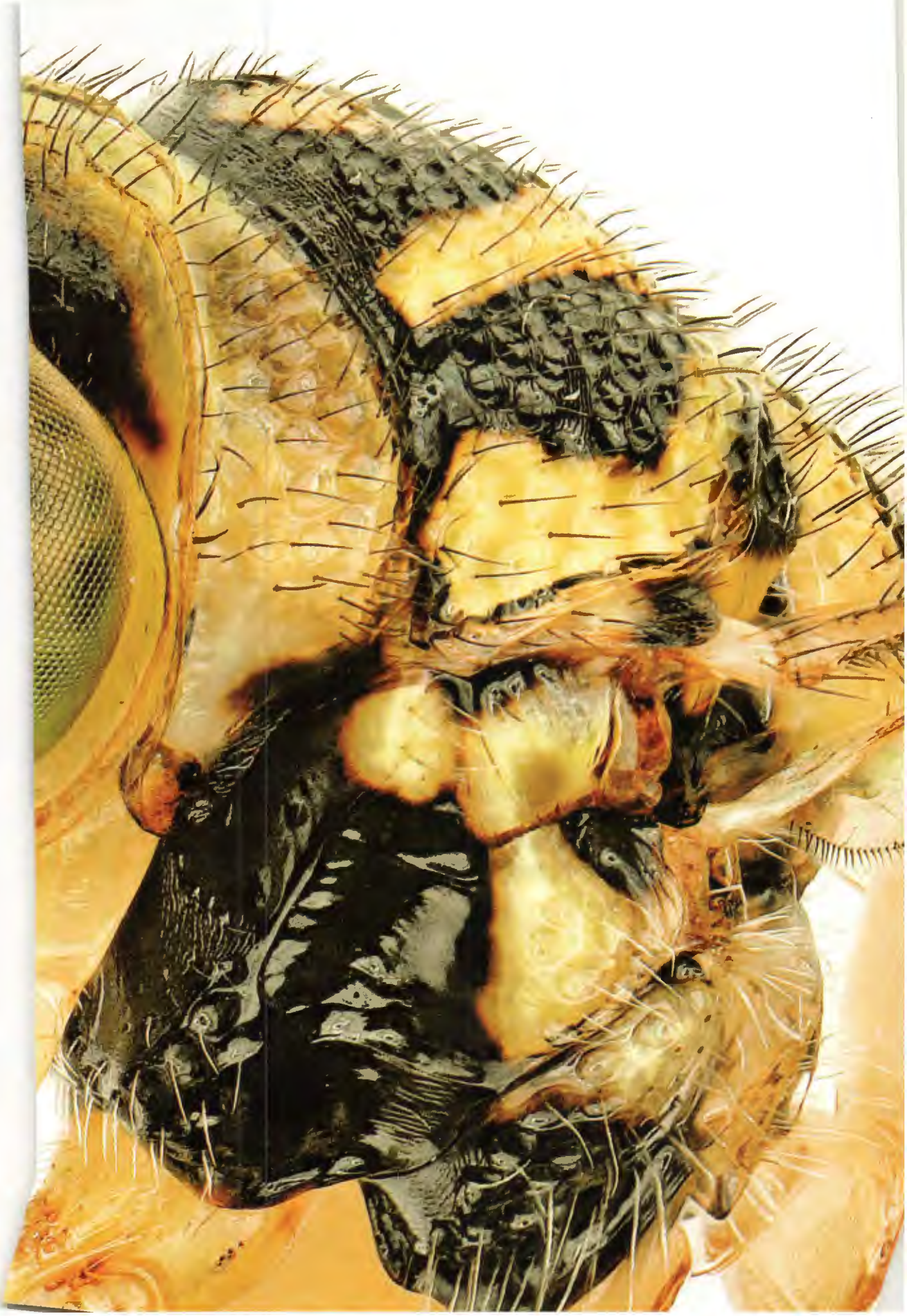
We were headed two hours northwest to a 40-meter (131-foot) steel tower that rises from a pristine area of rainforest. Built in 1979, the tower had long been used to track the exchange of carbon dioxide between the atmosphere and the trees. More recently, it also had become the site of a pioneering entomology experiment.

For years, dipterists had suspected that the fly species occupying the Amazon rainforest's floor differ from those found among its lofty trees, but no one knew how different they were.

After many visits to the tower for other experiments, Rafael got to thinking: What if he used the tower to find out? In 2017 he set five insect traps at various heights of the tower, starting at the ground level and spacing them every eight meters (26 feet), up to 32 meters (105 feet) high. He hoped doing so would reveal new insights into the stratification of insects in the forest.

Two weeks later Rafael returned with Amorim and was pleased to see the traps stuffed with insects. When the pair sent the samples

Usually smaller than a grain of rice, chalcidid wasps inject their eggs into other insects, which die after the eggs hatch and the new larvae start to feed on their hosts. The fuzzy jointed antennae on the wasps' faces help them seek out victims.



to colleagues for closer examination, their excitement grew. Of the more than 16,000 flies collected in two weeks, there were thousands of species that even experts couldn't immediately identify.

INSECTS ARE to the animal kingdom what the deep sea is to Earth: largely unknown to science. "We think because we know the birds and the mammals that we've already discovered what's on this planet. In fact, we've just scratched the surface," says Brown.

The Smithsonian Institution says that "there are more insect species that have not been described (named by science) than there are insect species that have been previously named." Flies are particularly diverse: More than 124,000 species have been identified, but scientists suspect countless more are awaiting discovery.

The Amazon is home to at least 10 percent of the world's known biodiversity and hundreds of thousands of insect species. But it's an uncertain time for the rainforest and for insects.

A 2019 study suggested that about a third of insect species would be vulnerable to extinction in the next few decades, a result of habitat loss from intensive agriculture, pesticide and fertilizer pollution, and climate change, among other factors. And in Brazil, President Jair Bolsonaro zealously has been promoting development of the Amazon, more than 300,000 square miles of which has been lost to industry since the 1970s.

Although it's common for scientists to stumble upon new insects in the Amazon, the volume of unfamiliar fly specimens caught in Rafael's tower traps was staggering. "It was like they discovered a new continent in terms of the level of novelty," Brown said.

Moreover, many species appeared only in traps set above the ground level. "Finding a separate fauna in the canopy was astonishing," Amorim said later. "Almost two-thirds of fly diversity is present in the eight- to 32-meter traps, but not in the soil. That means quite a lot of loss when big trees are cut down."

Many of the mystery flies seemed to be phorids, humpbacked creatures the size of a few grains of salt, some of which are parasitoids that jab their eggs into bees, ants, and other insects. Brown, one of the world's preeminent experts on the family Phoridae, knew he needed to see these new phorid species in the wild for himself—and as quickly as possible. "I always

Brian Brown prepares to suck a phorid fly into a tube for later study. He has spritzed leaves with diluted honey to attract the flies—and the bees they attack. "How many people," he asks wryly, "would voluntarily sweat in the forest surrounded by bees and wasps?"

Biodiverse basin
The Amazon Basin is rich in plant and animal species, especially insects. Each study location in the tropical rainforest has revealed species that are new to science.

MATTHEW W. CHWASTYK, NGM STAFF SOURCES: RAISG; GREENMARBLE

feel like we're one farmer and machete away from losing a whole bunch of species," he said ruefully.

He arranged an expedition with Rafael, Amorim, and Marshall, who had been his professor when he studied entomology at the University of Guelph. Their schedules aligned to meet in Manaus just after the New Year—and just before the coronavirus spread worldwide—in January 2020.

LIKE CHILDREN antsy to get to an amusement park, the dipterists squirmed excitedly as Rafael's truck bumped through the rainforest. When he turned onto the clay track that led to the tower, they could no longer contain themselves.

They burst out of the truck, left idling on the side of the deserted road, and crowded around a bush that buzzed with insects. Within minutes, they were catching critters with their bare hands.

"That's a ceratopogonid, I think," Brown said as he hunched over to look at the fly on Rafael's palm. Heloísa Fernandes Flores, a graduate student who conducts research with Amorim, rushed to collect it while Brown pointed out a tarantula hawk, a large wasp that preys on tarantulas and has one of the most painful stings in the animal kingdom. The dipterists were delighted to spot one; I was delighted it stayed a respectable distance from my face.

The next morning the scientists began working in earnest. Dressed in khaki hiking pants

TOP

José Albertino Rafael, a scientist with the National Institute of Amazonian Research (here wearing a headlamp to illuminate specimens), has wanted to study insects since he was a teenager. Growing up in Maringá, in southern Brazil, he collected butterflies, beetles, and other bugs. "My mother never wanted to clean my room because of the spiders," he says.

BOTTOM

Graduate student Heloísa Fernandes Flores works with Dalton de Souza Amorim at the University of São Paulo, where she's studying jackal flies. In 2019 she attended Fly School, a program Brown hosts and Amorim helps teach for people who want to learn more about flies. Historically, entomology has been dominated by men, but now Fly School tends to have more female students than male.

TOP

Dayse Willkenia Almeida Marques, now a fellow with the National Institute of Amazonian Research, studies Diptera—so-called true flies. On this trip she came across a phorid fly injecting its eggs into a caterpillar, to the delight of Brown, who'd never seen a caterpillar parasitized by a phorid.

BOTTOM

Amorim, a professor at the University of São Paulo, jokes that dipterists hate moths and butterflies because those insects' bright colors get them more attention and admiration than dipterists' flies. Plus, when they fly into traps, their scales slough off and coat other insects, making them hard to examine.

Known for their elongated snouts, weevils are one of the largest groups of insects. This weevil's iridescent neck, created by the flattening of hairlike structures, probably serves to attract mates or confuse predators.

1. Treehoppers come in a wide range of shapes. This one has camel-like humps.

2. This yet-to-be-named phorid fly species is a "parasitoid death-dealing machine" that jabs its eggs into other insects, Brown says. His colleagues insist it's "cute."

3. This treehopper evolved to mimic a thorn and blend in with the plants it eats.

4. Long-horned beetles' antennae can exceed the length of their body.

5. Turtle ants use their flattened heads as barricades to block the entrance to their nest when it's under attack.

6. Jumping plant lice are about the size of pinheads. This one boasts *Stegosaurus*-like spikes.

7. Jewel beetles have massive eyes. Their watchfulness means they can flee from predators quickly, so they're difficult for researchers to collect.

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tucked into rubber boots, Brown started most mornings by climbing to the tower's eight-meter (26-foot) level. There, he would remove a sizable bottle of diluted honey from his messenger bag and squirt it onto the leaves to lure bees and, by extension, the phorid flies that attack them, using sharp ovipositors to ram eggs into their bodies. He would repeat the same thing at 16 and 24 meters (52 and 79 feet), to see whether different flies showed up at higher elevations.

The swarms of petite stingless bees that arrived to feed on the honey proved irresistible to *Melaloncha*, or bee-killing phorid flies, which alighted on the leaves next to them.

"The flies curl their abdomen underneath their body, so the sharp part to attack the bees is right up under their head," Brown narrated one morning, watching a phorid chase down a bee through the viewfinder of his camera. "Then it gets in the right position and uses its ovipositor to jab an egg in between the hard parts of the bee."

When he was satisfied with his recordings, Brown would collect a few specimens with his aspirator, a long rubber tube attached to a rigid hollow tip, with mesh between them. He would put the rubber end in his mouth, scan the leaves for phorids, and point the rigid end at the flies he wanted to trap.

"You have to suck hard and be decisive," he said. "There's one." He pointed the tube at a barely visible speck and inhaled it into captivity.

Despite the oppressive humidity, Brown did not waste a second in the rainforest. When he wasn't collecting specimens or recording videos, he was scrutinizing his finds under a microscope or chatting with his fellow scientists about flies. He and Marshall, his former professor, spoke of other dipterists as if they were star athletes—referring to them by their last names only.

On one of our final mornings in the rainforest, we woke groggily after a night's sleep that had been interrupted by the incessant barking of the station's adorable, but loud, red mutts.

"I think they killed a possum," Amorim said, yawning.

Without missing a beat, Brown asked brightly:

Despite their shiny exteriors, jewel beetles are skilled at blending in. Species in this family range in color from brilliant blues and greens to duller browns, like this one. Their metallic shimmer can confuse predators such as birds and wasps.

"Does it have any bees on it?"

Brown's passion for flies is profound, but he recognizes that others might need convincing. One morning at the station, Brown and I talked about the importance of his work and the challenge of conveying it to others.

When he makes presentations to the public, Brown likes to explain that flies are nature's great recyclers. Fly larvae consume food waste, fallen leaves, dead animals, and feces, and they turn it all into nutrients that can be used by other creatures. Fruit flies, which share about 60 percent of their genes with humans, are crucial to genetics research. "And if people are totally cynical," he says, "I tell them flies pollinate cacao. Without flies, you wouldn't have chocolate."

Though life without Lindt sounded gloomy enough, I asked what else might happen if fly populations were to disappear.

As he focused the lens of a microscope to examine a new phorid species, he asked, Have you heard of the parable of the rivet popper by Paul and Anne Ehrlich?

I hadn't.

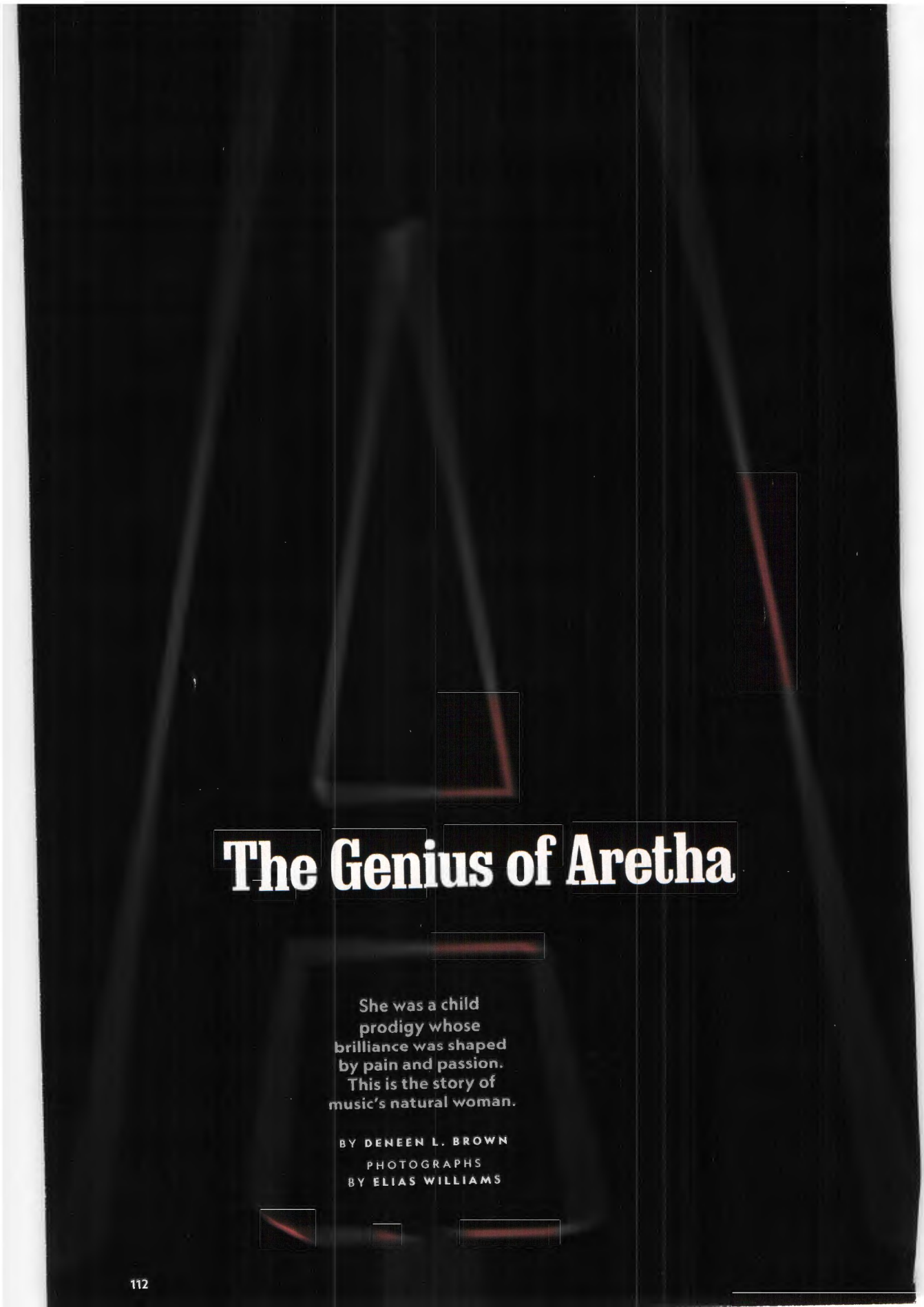
"Imagine you're on an airplane and you see someone popping rivets off the wing. So you talk to the guy, and he says, 'Oh well, we probably don't need all of these rivets. They're all doing more or less the same thing, and if we get rid of a few of them, it's not going to make any difference.'"

I told him that sounded frightening.

"That's the way that species are in ecosystems. People who don't care say, 'We're not going to miss a few phorid flies.' But at some point, we're going to get to where ecosystems aren't sustainable anymore."

Brown paused, letting the squawks, chirps, and croaks of the rainforest fill the air. Then he sighed, stood up, and began gathering his gear to head to the tower. □

This is writer **Haley Cohen Gilliland**'s first story for the magazine. Photographer **Craig Cutler** specializes in still life and environmental portraiture. Entomologist **Brian Brown** uses macrophotography to study insects.

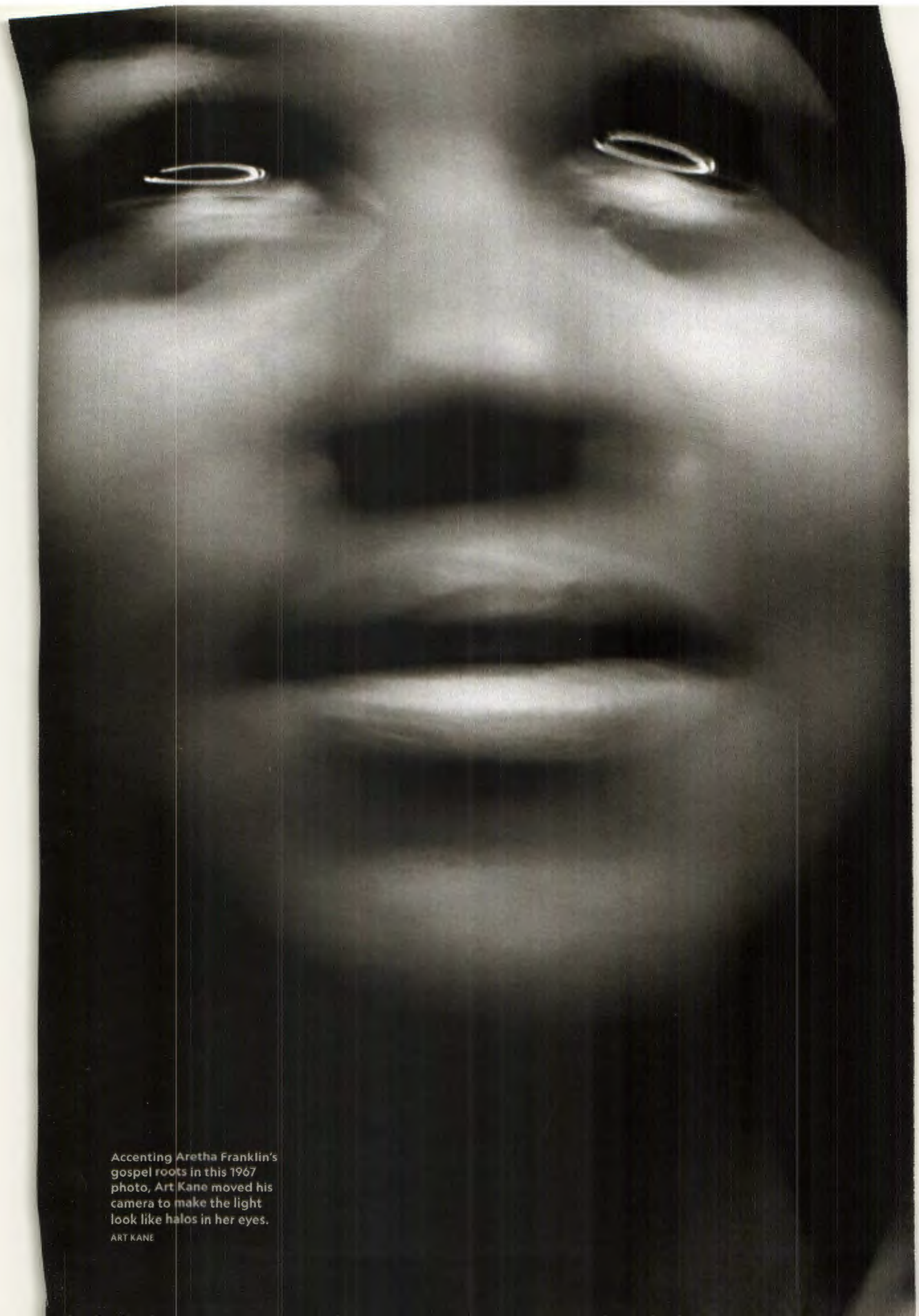


The Genius of Aretha

She was a child prodigy whose brilliance was shaped by pain and passion. This is the story of music's natural woman.

BY DENEEN L. BROWN

PHOTOGRAPHS BY ELIAS WILLIAMS



Accenting Aretha Franklin's gospel roots in this 1967 photo, Art Kane moved his camera to make the light look like halos in her eyes.
ART KANE

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KODAK SAFETY FILM

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WEARING A CRISP WHITE SHIRT and a black bouffant curled in a flip, Aretha Franklin seemed pensive but confident as she walked into the legendary FAME Recording Studios in Muscle Shoals, Alabama, in January 1967.

Franklin, just 24 years old, proceeded to take control with exceptional poise. She had not yet become a musical and cultural icon. She had not yet become Aretha Franklin, the Queen of Soul.

That day, she was largely unknown and a mystery. The studio musicians were not sure what to think. The creative tension was as thick as the cigarette smoke. It's hard to imagine now, but Franklin was desperate for a hit.

She had spent the previous six years recording a restrained kind of jazz at Columbia Records, without huge success. Now, at Atlantic Records, producer Jerry Wexler wanted to bring

GENIUS: ARETHA Cynthia Erivo portrays the Queen of Soul in an eight-part television series that premieres at 9 p.m. ET Sunday, March 21, on Nat Geo. It's available on Hulu the next day.

RIGHT
Franklin, seen here in 1968, produced a series of hits that became anthems for the civil rights and women's movements and for protests against the Vietnam War.

PREVIOUS PHOTO
A proof sheet shows Franklin singing a version of "The Weight," written by Robbie Robertson. She didn't read music but was able to arrange songs after hearing them.

ARETHA FRANKLIN, NEW YORK, OCTOBER 14, 1968 (CONTACT PRINT)
PHOTOGRAPH BY RICHARD AVEDON, © THE RICHARD AVEDON FOUNDATION
PREVIOUS PHOTO: MICHAEL OCHS ARCHIVES/GETTY IMAGES

out the "church" in Franklin. Musicians from FAME Studios had created a southern rhythm and blues sound that had produced a string of hits, including Wilson Pickett's "Land of 1,000 Dances" and Percy Sledge's classic "When a Man Loves a Woman."

Surrounded by a bunch of musicians who were unsure what kind of music they would make with her—Wexler had described them as a "rhythm section of Alabama white boys who took a left turn at the blues"—Franklin wasn't interested in small talk. She called them Mister So-and-So, and they called her Miss Franklin.

Then the preacher's daughter, raised in Detroit, Michigan, sat down at the piano. Musicologists later would explain that although Franklin did not read music and had no formal training, the piano was where she would summon her genius. The power of her voice was extraordinary on its own, a velvet force that seemed to reflect an ancient wisdom. Combined with her piano playing, it was glorious.

Without singing a word, she hit a chord on the piano. Then she straightened her back. Eyed the room. Touched up her frosted lipstick with her mouth. Every man in the room took notice.

When she began to sing, she hit a "hell knows no fury like a woman scorned" note that threatened to peel the paneling.

Her voice exploded with raw emotion. Producers would describe what erupted from Franklin that day in Muscle Shoals as otherworldly.

She pounded the piano as if the keys marked a thin line between love and hate. Then she hit a low note and took it to church.

That recording of "I Never Loved a Man (The Way I Love You)" would catapult Franklin to fame.

The men in the band would say they'd never seen or heard any singer like her. The power of her voice, the strength of her storytelling, and the way she was able to channel that intangible thing called soul—brilliant.

"I can tell you what I saw," Spooner Oldham, a legendary organist and songwriter, told me in an interview. Oldham, a Rock & Roll Hall of Famer, has seen some outstanding acts. He's played with Neil Young, Bob Dylan, and many more icons of music. But that first recording session with Franklin was something else, he said.

"It was not talked about or planned. She just started playing. I knew I was working with someone special," Oldham said. "Her voice was hard to describe. It covered so much territory. It was angelic. Soulful. Upbeat. Downbeat. If you start naming adjectives, you would name it all. She was one of a kind. I thought she was a musical genius right then."

During that session Franklin, backed by the renowned Muscle Shoals Rhythm Section, recorded the first of many million-selling records. "They finished the track, and everybody in the room knew it was a hit record," Rodney Hall, son of FAME Studios co-founder Rick Hall, told me.

LEFT

Aretha Franklin was born in this now abandoned house in South Memphis, Tennessee. When she passed away in August 2018, people brought flowers and left messages or the lyrics of their favorite songs. Some locals would like to recognize Franklin by having the house preserved as a historic landmark.

RIGHT

A portrait of Clarence LaVaughn "C.L." Franklin, Aretha's father, still hangs at New Salem Baptist Church in Memphis, where he was pastor in the early 1940s.

We Walk...
That he shall not
Dogs Hate Like Best Friends
Join N.A.A.C.P.
FOR HIM!
Bagel

In 1963 C.L. Franklin organized the Walk to Freedom in Detroit, Michigan, where Martin Luther King, Jr., delivered an early version of his "I Have a Dream" speech. More than 125,000 people attended the march. C.L. Franklin, standing left of King, was his adviser. After King was assassinated in 1968, Aretha Franklin sang "Precious Lord" at a memorial service.

WALTER P. REUTHER LIBRARY, ARCHIVES OF LABOR AND URBAN AFFAIRS, WAYNE STATE UNIVERSITY

THE SOURCE of some of the pain Franklin sang so passionately about would become clear by what happened next. The recording session ground to a halt as all hell broke loose in the studio.

Franklin's husband-manager, Ted White, accused a trumpet player of flirting with his wife and demanded that the musician be fired. Rodney Hall later recalled his father telling him that the night ended with Rick Hall and White trying to throw each other off a balcony of the hotel where Franklin was staying.

The messy scene was a window into Franklin's private world. She would channel her pain and infuse soul into songs that would become universal, crossing musical genres and spanning time, generations, and cultures. That night in Alabama would set her on a course to drive popular music for decades and take the sound of soul to new heights. Her voice would become the revolutionary sound of women, African Americans, and others demanding to be recognized.

Just days after leaving Muscle Shoals, Franklin would record another hit, "Do Right Woman, Do Right Man," in a studio in New York City. A week later, she recorded "Respect," which would become an anthem not only for Franklin's power in the music industry but also for women's rights at a volatile time.

MORE THAN 50 YEARS after Franklin's epic recording session in Muscle Shoals, and nearly three years after her death at age 76, her brilliance remains something of an enigma. Her long and successful reign as the Queen of Soul is undisputed. That she could sing the deepest of blues, the funkiest of funk, finger-popping pop, silky jazz, powerful rhythm and blues, soul-stirring gospel, and even dramatic opera with phenomenal ease is undisputed. That she was a musical genius unmatched in her range, power, and soul is undisputed.

Much as Albert Einstein pushed the boundaries of science and Pablo Picasso created a new art form, Franklin extended the sound of music to new depths, arranged it, expanded it, captured it, composed it, made it her own, and ruled over it for more than six decades.

But what, exactly, was the root of Franklin's artistry? Like other geniuses, she was a child prodigy, her gift recognized early and nurtured by her father. As with Picasso and Einstein, she had a dominant personality and a keen sense for detail. Franklin had an acute ear that allowed her to break down the melodic threads of a song and arrange them to her liking. She also had an intense ambition and drive to make hit records. Even as her health was failing in her later years, she wanted to get back into the studio and make music.

IT WAS THE WAY SHE USED HER VOICE, SUCH AS WHEN SHE JUMPED OCTAVES, THAT REVEALED HER GIFT.

"Aretha's genius was very, very natural to her," music mogul Clive Davis told me. "She felt, embodied, and was able to perform music like no one else before her."

Davis, who worked with Franklin for 38 years, said her genius lay in her ability to take songs deeper—sometimes deeper than the songwriters had intended. "She understood the essence of both language and melody and was able to take it to a place very few—if any—could," he said.

"Aretha never had a music lesson," said Brenda Corbett, a cousin who sang backup for Franklin for more than 50 years. "She knew exactly what she wanted. If it wasn't right, she would let you know."

Franklin's phenomenal vocal range seemingly climbed as high as a mountaintop before plunging to painful depths. Some musicologists say her voice pushed four octaves. But it was the way she used her voice, such as when she jumped octaves on musical bridges, that revealed her immeasurable gift. That's when anyone listening got goose bumps.

"Often genius is conceived in terms of a high score on an IQ test, a conception I tend to disfavor," said Dean Keith Simonton, a professor emeritus of psychology at the University of California, Davis. "Other times genius will be defined as exceptional early talent in a particular domain," he said. "And yet other times genius will be attributed to those who have left a pervasive and enduring impact."

Child prodigies, experts say, often seem to be old souls, performing at levels far beyond their

years. As children, they can seem chillingly advanced, awing others as they master complex sonatas or science and math equations.

In Franklin's case, her musical talent was evident from the start.

SHE WAS BORN Aretha Louise Franklin on March 25, 1942, in South Memphis, Tennessee. Her father, the Reverend Clarence LaVaughn "C.L." Franklin, was a prominent Baptist preacher. Her mother, Barbara Siggers Franklin, was a highly regarded gospel singer.

The family moved to Buffalo, New York, from Memphis and then to Detroit, where her father became pastor of New Bethel Baptist Church. When Aretha was six years old, her mother left the family. Aretha, her brother, and her two sisters were raised by their paternal grandmother—who lived in their home for a time—but Aretha longed for her mother, who died suddenly a few years later.

"It happened when I was 10," Franklin said in *Aretha: From These Roots,* an autobiography she wrote with David Ritz. "Daddy called all of us—me, Erma, Carolyn and Cecil—into the kitchen. As he sat at the end of the sink, which resembled a sideboard, he said it plainly and solemnly. Our mother had suffered a fatal heart attack. I just stood there, stunned. I cannot describe the pain, nor will I try. Pain is sometimes a private matter, and the pain of small children losing their mother defies description."

It was a childhood trauma, relatives say, from which she never really recovered—a sadness she carried for the rest of her life.

It's also clear that Franklin was influenced by the talent of her father, a celebrated performer in his own right. C.L. Franklin was known well beyond Detroit, because recordings of his sermons were best sellers. His most famous sermon, "The Eagle Stirreth Her Nest," from 1953, is "arguably the most demanding sermon in the African-American Baptist tradition," wrote Nick Salvatore, author of *Singing in a Strange Land: C.L. Franklin, the Black Church, and the Transformation of America.*

Aretha was in her early teens when she joined her father on the gospel circuit. C.L. Franklin recognized his daughter's brilliance, and showed her off as they traveled from church to church. He'd preach, and then she would sing.

Aretha made her first record at 14—according to some sources, about two years after she had given birth to her first child, Clarence, and the age at which she would have her second child, Eddie.

One 1960 concert poster from Chattanooga, Tennessee, advertises a sermon by C.L. Franklin with his 18-year-old daughter, Aretha, "a rising star in the gospel-music field." According to Jason Hanley, a musicologist and vice president of education and visitor engagement at the Rock & Roll Hall of Fame in Cleveland, Ohio, "The Reverend Franklin is actually the headliner there. Then his incredible daughter, this prodigy, Aretha Franklin, is performing the gospel message her father is talking about."

Jeff Ramsey, a professor in the voice department at Berklee College of Music in Boston, said that the time Aretha Franklin spent in church choirs and on the gospel circuit helped polish her genius—that the circuit gave her a wisdom formed by the history, pain, and resilience of Black people in the United States. Her roots were gospel, and "what never changed was the sacredness of her voice," Ramsey said.

In Ritz's biography, *Respect: The Life of Aretha Franklin,* Franklin's brother, Cecil, said that he and his sisters had musical talent but that Aretha "was born with it. Later on, musicologists can try to analyze how she came to it. They can say that she practiced harder than the rest of us or paid more attention to the music around her or was more motivated to learn. But I'm here to tell you that none of that is true. She didn't practice. She didn't pay any more attention to the music around her than Erma, Carolyn, or myself."

He added that "we always knew that she possessed a different kind of talent. That's the talent they call genius. You can't learn it. You just have it."

GENIUS CAN BE NURTURED in an environment that gives it room to grow. Geniuses often have huge personalities, enormous ambition, competitiveness, and an ability not to shrink around other talented people.

THAT'S WHEN ANYONE LISTENING GOT GOOSE BUMPS.

Queens of the Charts

Women With All-Time Most *Billboard* Hot 100 Entries

Taylor Swift
128 hits

124 lead/4 featured

First hit
"Tim McGraw" (2006)

"Closure" (2020)

Swift, who started her career in country music before expanding into pop, is the lead performer on almost all her hits.

Aretha Franklin
73 hits

73 lead

First hit
"Won't Be Long" (1961)

"Here We Go Again" (1998)

Franklin held the record for the most hits by a female artist for 40 years, 1977 to 2017.

Nicki Minaj
114 hits

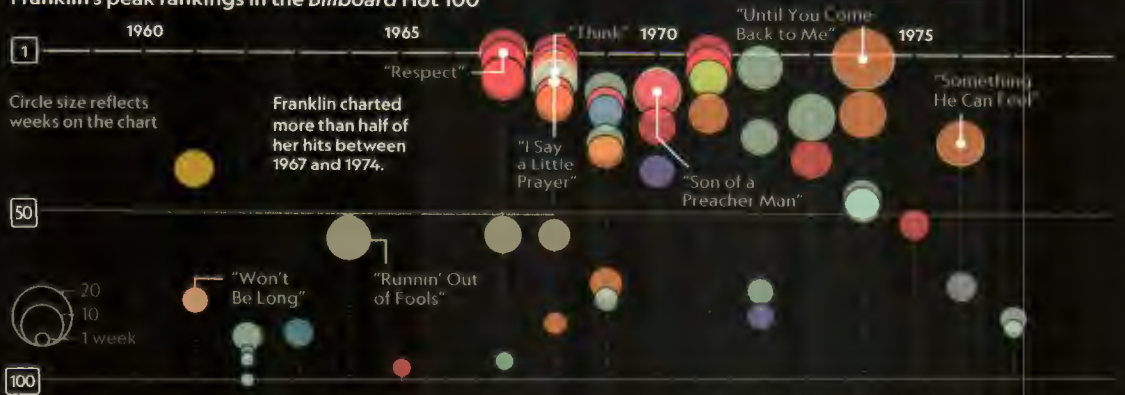
51 lead/63 featured

First hit
"Knockout" (2010)

"What That Speed Bout!?" (2020)

Minaj is featured on 63 songs by others, including two each by Ariana Grande and Madonna, and one by Beyoncé.

Franklin's peak rankings in the *Billboard* Hot 100



Franklin charted more than half of her hits between 1967 and 1974.

MONICA SERRANO, NGM STAFF; ALEXANDER STEGMAIER SOURCES: *BILLBOARD*; SHANA L. REDMOND, UCLA. GENRE DETERMINATIONS ARE BASED ON SCHOLARLY INTERPRETATION. THE *BILLBOARD* HOT 100 RANKS SONGS BY WEEKLY STREAMING, RADIO AIRPLAY, AND SALES. DATA AS OF DECEMBER 26, 2020.

Aretha Franklin's genius redefined music and spanned genres, helping her amass 73 hits—songs ranked in a week's 100 most popular by *Billboard*—over her 60-year career. Today her timeless talent still shines bright among the top seven female hitmakers of all time.

GENRE (lead artist)

- R&B
- Pop
- Blues
- Gospel
- Country
- Funk
- Soul
- Rap
- Dance/disco
- Other

SONG CREDIT

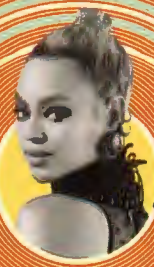
- Featured artist

Rihanna
62 hits

47 lead/15 featured

First hit
"Pon de Replay" (2005)

"Believe It" (2020)



Beyoncé
65 hits

53 lead/12 featured

First hit
"03 Bonnie & Clyde" (2002)

"Black Parade" (2020)

Ariana Grande
67 hits

60 lead/7 featured

First hit
"The Way" (2013)

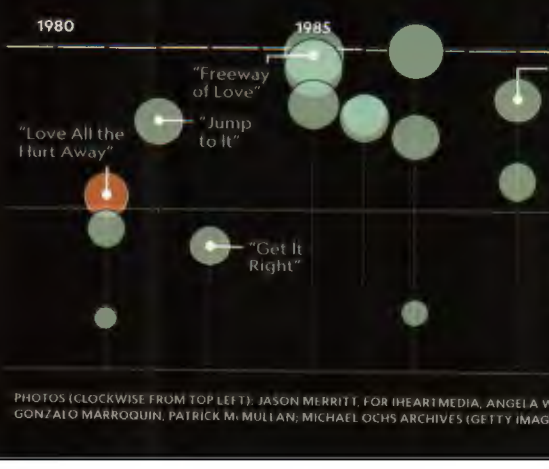
"Oh Santa!" (2020)

Madonna
57 hits

56 lead/1 featured

First hit
"Holiday" (1983)

"B**** I'm Madonna" (2015)



All combined, Franklin's songs lived on the Hot 100 for 655 weeks, equivalent to almost...

13 years

Franklin's last hit on the Hot 100 chart was "Here We Go Again," peaking in popularity in August 1998.

PHOTOS (CLOCKWISE FROM TOP LEFT): JASON MERRITT, FOR IHEARTMEDIA, ANGELA WEISS, AFP; CHRIS WALTER, WIREIMAGE (TWO); KEVIN MAZUR; GONZALO MARROQUIN; PATRICK M. MULLAN; MICHAEL OCHS ARCHIVES (GETTY IMAGES: ALL)

In Detroit, Aretha Franklin grew up in a city that would produce a litany of Motown stars: Diana Ross, "Little" Stevie Wonder, Berry Gordy, Smokey Robinson, the Temptations. Even among all that talent, Aretha Franklin stood out. Robinson said he first saw a young Aretha when he was eight years old.

Robinson, who became friends with Cecil Franklin, described his first encounter with Aretha at the Franklin family home. "We're walking around the house, and I hear music," Robinson told the crowd at Franklin's funeral. "The piano being played, and this voice, it sounds like a little girl singing. And I go and look in that room, and I see you, and you're there and you're singing."

As a little girl, Aretha occasionally was pulled from sleeping to perform for stars who were visiting her famous father. In that parlor she met gospel singers Clara Ward and Mahalia Jackson, singer-songwriter Sam Cooke, composer and band leader Duke Ellington, jazz pianists Art Tatum and Oscar Peterson, singers Ella Fitzgerald, Dinah Washington, Nat King Cole, Lou Rawls, and Billy Eckstine, and the Reverend Martin Luther King, Jr.

FRANKLIN'S GENIUS was on full display on her debut R&B album when she remade "Respect," written by legendary soul singer Otis Redding. His song was meant to be about a man demanding respect when he comes home. Franklin's version was about a woman making that demand, and she spelled out each letter of the word "respect" in the lyrics.

Redding reluctantly would admit that Franklin made the song hers. During the Monterey Pop Festival in 1967, Redding told the crowd: "Now, there's something we'd like to do for everybody. It's a song a girl took away from me.

A good friend of mine, this girl, she just took the song. But I'm still going to do it anyway." Then he launched into an up-tempo version.

That year Franklin won her first Grammy Awards honor for Best Rhythm & Blues Recording and Best Rhythm & Blues Solo Vocal Performance by a woman for "Respect." She would go on to win 17 more Grammys and receive 44 nominations for the award, presented by the Recording Academy to honor excellence in the recording arts and sciences.

Music fans got an unexpected glimpse of the stunning range of Franklin's talent at the 1998 Grammy Awards ceremony in New York. Luciano Pavarotti, the world-renowned Italian tenor, was scheduled to perform "Nessun Dorma," the great aria written by Giacomo Puccini. But Pavarotti called the set of the live broadcast and said he was sick.

Franklin had been scheduled to perform with the Blues Brothers—Dan Aykroyd, John

LEFT
Singer Meagan Connors (at left) and Spooner Oldham (center) rehearse at FAME Recording Studios in Muscle Shoals, Alabama. Oldham was a studio musician at FAME when Franklin recorded there in 1967.

RIGHT
The piano that Franklin played for what became her first million-selling record, "I Never Loved a Man (The Way I Love You)," sits in the family home of a FAME executive. FAME produced many chart-topping records and was influential in developing the Muscle Shoals sound.

1st Session.

1. My Way - I would like to record Vocal.

Strings 2. The Thrill is gone - Be sure the piano and bass are dominate! + Button in spot's!

Strings 3. "You + Me" - Use Sweet Inspiration's to put the top on!

Horns 4. Why I'm Singing the Blue's - A good taste of Cornell Dupree (WOW) + make piano in the solo part.

Done 5. Spirit in the Dark - The Sweet Inspiration's up the bass in spot's, some turn Around's! Tambourine's on fast part + cancel or lower guitars on same part

Done 6. One Way Ticket - be sure of 3 blend's in voice's like I know you will (smile) Cut off maybe 2 bars of the top of the fade + get the best of end of the end!

Horns 7. Who Will Wear the Crown
Voice blend's + Rhythm ~~guitars~~ guitars Cut rythm guitars if possible in spot's at your discression + refined taste (smile)

Horns 8. Honest I do - up piano as long as it's good in solo.

II

Horns 9. That's All I want from you
a little More of the girls in /
bkgrnd y + highly possible I should Redo my vocal.

Horns 10. Don't Play It No More
- Swinging !!!!!!
King Curtis + the pastor (Melvin) + that group touch up??

11. [redacted] - Oh No not my baby -
Just a touch more of the girls in the
fade ... + Arif's strings and a
Strings groove would be to start them on A low F to
a high F like Ah Ah ! like Sissie's approach
to Ain't no way the first note's

Dear Jerry:
if the record's flunk on
my suggestions combined with yours I
had nothing to do with it!
HA HA HA.

Aretha

Aretha Franklin's handwritten notes from a recording session for her 1970 album *Spirit in the Dark* show her composing and arranging talent, as well as her sense of humor.
ROCK HALL LIBRARY & ARCHIVES

Franklin seems to relish her stardom in an early 1970s portrait. She was known as the Queen of Soul for a half century. "There will never ever be another Aretha Franklin," music mogul Clive Davis has said. "Aretha was a true genius of American music."

MICHAEL OCHS ARCHIVES/ GETTY IMAGES

Goodman, and Jim Belushi—on the Grammy show that night. But Ken Ehrlich, the show's executive producer, remembered that Franklin had sung "Nessun Dorma" two nights earlier at a benefit for the Recording Academy. "I just ran up to her dressing room and asked her if she would do it," Ehrlich later told *Billboard*.

What followed was one of the signature moments of Aretha Franklin's career. Neither a tenor nor an opera singer, she performed the aria beautifully.

"She had to change keys because she had to use Pavarotti's arrangement," Ritz said. She listened to the orchestration for 20 minutes and figured how to change her voice to a key that wasn't her first choice. She turned it into a soul song but honored the beauty of Puccini's melodic gift.

Franklin told me in a 2012 interview that "Nessun Dorma" was among her favorite songs. "There are too many" songs to name, she said, when asked about those she liked best. "Certainly among them would be 'Respect,' 'Jump to It,' 'Natural Woman,' 'Rock Steady,' and 'Nessun Dorma,' Pavarotti's signature song."

There was no hint of bravado in her voice.

THE ONLY TIMES SHE RELEASED THE PAIN SEEMED TO BE WHEN SHE SANG.

IN 1987 FRANKLIN became the first woman inducted into the Rock & Roll Hall of Fame, blazing a trail for female Hall of Famers. *Rolling Stone* placed her at number one on its Greatest Singers of All Time list. In 2019 she won a posthumous Pulitzer Prize Special Citation.

Franklin gave countless iconic performances—including stepping on stage in a luxurious fur coat that fell off her shoulders and a canary yellow gown to sing "I Dreamed a Dream" at an inaugural event for President Bill Clinton in 1993. The song was a classic from the musical *Les Misérables*. She commanded the song and the stage. When she dropped her fur and then hit a high note, the crowd and the Clintons rose to their feet.

"Everyone in the audience was transfixed as the performance kept building," Davis recalled at Franklin's funeral. "Then the one and only Aretha, on her own, spontaneously changed the lyrics from 'I dreamed a dream' to 'I have a dream,' and that instinctive switch to the Martin Luther King mantra made the climax chillingly unforgettable to this day."

She sang "My Country, 'Tis of Thee" at the 2009 inauguration of President Barack Obama, where she wore a gray hat that has its own social media following and is listed among the assets in a civil dispute over her estate in Detroit.

"Aretha helped define the American experience," Obama tweeted after her death. "In her voice, we could feel our history, all of it and in every shade—our power and our pain, our darkness and our light, our quest for redemption and our hard-won respect."

Franklin's courage and legend extended beyond her music. She helped finance the civil rights movement, marched with King, and sang at a memorial service for the civil rights leader in 1968. She created music that became the soundtrack for revolutions: the civil rights and women's movements, and protests against the Vietnam War.

In 1970 she offered to pay up to $250,000 to bail political activist Angela Davis out of jail. "Black people will be free," Franklin told *Jet* magazine then. "I've been locked up" for disturbing the peace in Detroit, "and I know you got to disturb the peace when you can't get no peace. Jail is hell to be in. I'm going to see her free if there is any justice in our courts, not because I believe in communism, but because she's a black woman and she wants freedom for black people. I have the money; I got it from black people—they've made me financially able to have it—and I want to use it in ways that will help our people."

Franklin sang the songs that became, for many of us, the background music of our childhoods. We danced to "Chain of Fools" in bell-bottoms in the 1970s. We learned to spell singing "Respect," and demanded it. We grew our natural hair into Afros like Aretha's. When we woke up, it was her song about young love that came to mind: "I Say a Little Prayer for You."

You might be too young to have seen Franklin in her prime, but you probably have heard her music. Your mother and father most likely know it. You've heard it at the movies. And you've

heard Aretha's style of singing in artists such as Beyoncé, Ariana Grande, Fantasia, Jennifer Hudson, Lady Gaga, Whitney Houston, and Adele.

At the Rock & Roll Hall of Fame's 16th American Music Masters Tribute, which honored Franklin in 2011, a suite of artists serenaded Franklin with her songs. Franklin wasn't supposed to perform that night in Cleveland. But during a break in the show, she demanded a piano.

Aretha ascended to the stage with Ronald Isley, Cissy Houston, Jerry Butler, and Dennis Edwards to perform an encore.

"They launch into this incredible song," the Hall of Fame's Hanley recalled. "She is in charge. In that moment, the whole world shrunk down to her spotlight. We were all witnesses. That is when I personally realized why she is who she is."

BIOGRAPHER RITZ, who cowrote Franklin's autobiography in 1999 and wrote his own book about the singer 15 years later, called her an engineer. He told me that part of Franklin's genius lay in how she deconstructed others' songs she had decided to cover: In the studio she'd take a song apart, infuse it with soul, then add her original groove. When she put the song back together again, she mastered it. "She does a big band version of a hit by Glen Campbell called 'Gentle on My Mind,'" said Ritz. "It was a country song with jazz, groove, and big band, and she kills it." Her intelligence, he said, was manifest "in the intensity of her emotional expression." It was born of her personal pain, depression, and desire never to talk about her story or what hurt her.

In an early interview, a young Franklin smiles nervously as she sits at a piano. White, her husband, sits next to her. Her hair is pulled back, and her face is soft and innocent. She tells the camera in the voice of a girl: "I'm still trying to find out who and what I really am."

In a 2012 interview with me, she answered every question but one. She bristled when I asked her to recall her earliest childhood memory.

"Her whole life, she kept it very secret what was happening with her life, from the romantic to the personal," Ritz said. "You couldn't get any information out of her. She suppressed anger. She suppressed her confusion. The one vehicle she used to express it all was her music. Because it was suppressed, it was extravagantly expressed."

The only times she released the pain seemed to be when she sang. And when the pain erupted, it was astronomical.

Ritz spent years with Aretha trying to tell her story. "Some of us go and pay the psychologist or psychiatrist and shut the door," he said. "She does it by opening her mouth on stage. This is her psychotherapy. Her catharsis."

IN ATLANTA, Georgia, National Geographic filmed the third season of *Genius*, a scripted series that in previous seasons focused on Einstein and Picasso. The eight-episode season stars Cynthia Erivo as Franklin.

Suzan-Lori Parks is showrunner and executive producer for *Genius: Aretha*. Parks, a Tony winner and Pulitzer Prize–winning playwright, sits on the sofa in a living room set that transports you back in time. It's designed to replicate Franklin's childhood home in Detroit and help reimagine the life of young Aretha. The sofa and two love seats are covered with protective plastic. Cigarette butts are scattered in ashtrays. A grand piano sits in the corner of the room. A staircase frames the living room.

It was in a living room like this that Franklin heard the great Mahalia Jackson, Sam Cooke, and Clara Ward. At a piano like this, she would sit on the bench next to the inimitable James Cleveland, who taught her chords. In a kitchen like this, Big Mama, as she called her grandmother, and the cooks her father hired prepared southern soul food—fried corn, black-eyed peas, chicken and dumplings, greens, and sweet potato pies.

Parks was determined to capture Franklin's genius for the "definitive series of the universally acclaimed Queen of Soul," she said. She continued, "And while everyone who listens to Western popular music knows the sound of her voice, very few people know her story, know the pain she struggled through, know the difficulties of her childhood, know that her mother died at a young age, know she didn't just burst onto the scene and find her sound."

AND WHEN THE PAIN ERUPTED, IT WAS ASTRONOMICAL.

Franklin wore a high-collared coat as she closed out her concert at the JVC Jazz Festival in June 2000, held at New York City's Lincoln Center. Her show included a powerful rendition of Puccini's "Nessun Dorma" aria, echoing her last-minute performance at the 1998 Grammy Awards.

JACK VARTOOGIAN, GETTY IMAGES

Franklin didn't have it all figured out when she started singing, Parks said. She "dug down deep and made something beautiful out of her life that endures and lights the way for all of us."

Geniuses create light for generations, Parks said. "Harriet Tubman was a genius. Einstein was a genius. Edison was a genius. Da Vinci was a genius. Bach was a genius. [John] Coltrane was a genius. Toni Morrison was a genius," she said. "These are people who create not just things that are fashionable, but things that deeply endure."

Across the studio Erivo is in hair and makeup, transforming into Aretha, summoning the genius and the diva. In 2016 Erivo felt as though she and Franklin sang together—if just for a moment. Erivo, dressed in a white lace gown, stood on stage at the Kennedy Center Honors, performing "The Impossible Dream." Just as Erivo was about to hit a spiraling note, the camera cut to the audience. And there was Franklin, eyes closed, singing the words with her.

The moment was fleeting but powerful. Erivo told me she watches the video clip often. "I'm really glad I got to do something that she enjoyed," Erivo said, "and that I was one of the voices that brought her some happiness."

Erivo, who has won a Grammy, Emmy, and Tony for her Broadway performance in *The Color Purple,* met Franklin backstage after a show. Erivo was nominated for two Academy Awards in 2020—for Best Actress and Best Original Song—for playing the role of abolitionist Harriet Tubman in the film *Harriet.*

Now she's transforming into the Queen of Soul. "To be able to play an icon like Aretha, who is one of my idols, is kind of incredible," said Erivo, who grew up in the United Kingdom, where she began listening to Franklin's music as a child.

Erivo said she prepared for the role by reading, listening to music, and watching the soul-stirring documentary *Amazing Grace,* which was

released after Franklin died and features her as she records a live album in 1972.

The film, shot over two nights at New Temple Missionary Baptist Church in the Watts section of Los Angeles, reveals a 29-year-old Franklin returning to her gospel roots. Directed by Sydney Pollack, it captures rare footage of Franklin in a transcendent performance. On the second night, Charlie Watts and Mick Jagger of the Rolling Stones squeezed into the audience.

The film also captures Franklin's father sitting next to Ward, who became a mentor to Franklin.

"I've watched it religiously. It gives you a great insight into who she was," Erivo told me. "When she gets to the bridge of the song, something happens and she opens up completely. That is when you feel her heart." □

DeNeen L. Brown interviewed Aretha Franklin in 2012. **Elias Williams** photographed *National Geographic* magazine's February 2020 feature about the slave ship *Clotilda*.

LEFT

Franklin is depicted in a mural painted by Detroit artist Fel'le next to his art gallery. In 2017 Detroit named a section of a street Aretha Franklin Way. An amphitheater is also named for her. In addition, the state of Michigan designated a portion of a Detroit freeway the Aretha L. Franklin Memorial Highway.

RIGHT

The Detroit Youth Choir performs at a tribute on August 16, 2019, the first anniversary of Franklin's death. "She never forgot where she came from and how she started," said city council president Brenda Jones.

INSTAGRAM

STEPHANIE SINCLAIR

FROM OUR PHOTOGRAPHERS

WHO

A photographer who covers the exploitation of girls, Sinclair also leads Too Young to Wed, a nonprofit working against gender-based violence.

WHERE

Kasturba Gandhi Girls School in Bihar, India

WHAT

A Canon 5DS R camera and 24-105mm lens

As part of Sinclair's work against gender-based exploitation and violence, in 2016 she visited a school in Bihar state that aims to break the bonds of caste and inequality for the girls who live and study there. Sinclair bunked in a school office so she could stay for several days. She photographed girls in their daily routines, watching them find their identities and confidence. A few of the school's graduates have gone on to college, with ambitions of becoming lawyers and doctors.

This page showcases images from National Geographic's Instagram accounts—the most popular brand on Instagram. Join more than 218 million followers: **@natgeo, @natgeotravel, @natgeointhefield, @natgeoadventure, @natgeoyourshot.**

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LEGAL NOTICE

If you purchased Hill's Prescription Diet or Science Diet Canned Dog Food

Between September 1, 2018 and May 31, 2019, Your Rights May Be Affected by a Class Action Settlement.

WHAT IS THIS LAWSUIT ABOUT?

A Settlement has been reached in a class action lawsuit called *In Re: Hill's Pet Nutrition, Inc. Dog Food Products Liability Litigation*, Case No. 19-md-2887-JAR-TJJ, pending in the U.S. District Court for the District of Kansas. The lawsuit claims that certain Hill's Prescription Diet and Science Diet canned dog food products had high levels of Vitamin D. The lawsuit alleges that purchasers of these products lost money by purchasing dog food products that were not manufactured as represented and/or paid for veterinarian services as a result of injuries to their dogs.

Defendants deny that class action lawsuits are the most appropriate, efficient or comprehensive way to help consumers whose pets may have been affected by the recall. Defendants are entering into this settlement to avoid burdensome and costly litigation and to focus on timely addressing consumer complaints.

WHO IS INCLUDED?

You are included in the Settlement if you purchased Hill's Prescription Diet and/or Science Diet canned dog food products in the U.S. between September 1, 2018 and May 31, 2019. A detailed list of products is available at **www.PetFoodSettlement.com**.

WHAT DOES THE SETTLEMENT PROVIDE?

Consumer Food Purchase: If you purchased Hill's Prescription Diet and/or Science Diet canned dog food products between September 1, 2018 and May 31, 2019, you could get a **full refund with Proof of Purchase or up to $20 total without Proof of Purchase**. You must submit a valid Claim Form by **July 2, 2021**.

Dog Injury: If your dog suffered injuries consistent with the consumption of excess Vitamin D as a result of your dog eating Hill's Prescription Diet and/or Science Diet canned dog food products, you could receive money. You must submit a valid Claim Form with proper documentation by **July 2, 2021**.

You can find more details on how to submit a claim by visiting **www.PetFoodSettlement.com** or calling **1-833-537-1191**.

WHAT ARE YOUR OPTIONS?

- **Do Nothing.** You will not receive any benefits from the Settlement. You will be legally bound by decisions of the Court and you give up your right to sue Defendants relating to the claims resolved by this Settlement.
- **Exclude Yourself.** If you do not want to be included in the Settlement, you must submit a written request to the Settlement Administrator, Settlement Class Counsel, and Defendants' Counsel by **June 21, 2021**. You will keep your right to sue Defendants about the claims in this case, but you will not receive money. Detailed instructions on how to exclude yourself are found on **www.PetFoodSettlement.com**.
- **Object/Comment**. You have the right to object to or comment on the Settlement and still get benefits. If you want to object to or tell the Court what you think about the Settlement, you must submit your objection/comment in writing by **June 21, 2021**. Detailed instructions on how to object or comment are found on **www.PetFoodSettlement.com**.

The Court will hold a hearing on **July 27, 2021**, at **10:00 a.m.** by Zoom Video, which may be moved to a different location, time or date. The Zoom Video link will be posted on **www.PetFoodSettlement.com**. At the hearing, the Court will hear objections, determine if the Settlement is fair, reasonable, and adequate, and consider Settlement Class Counsel's request for fees and expenses and a Service Award for the Class Representatives. You may attend the Final Approval Hearing and ask to be heard by the Court, but you do not have to attend. Attorneys' fees and expense requests will be posted on **www.PetFoodSettlement.com** after they are filed with the Court.

This is only a summary. For more information about the settlement and benefits, visit **www.PetFoodSettlement.com**, call **1-833-537-1191**, or write to Hill's Pet Food Settlement Program, c/o Settlement Administrator, PO Box 97, Warminster, PA 18974-0097.

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